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Scientific and Technical Revolution: Economic Aspects

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PROGRESS PUBLISHERS
MOSCOW

Translated from the Russian by *Yu. Sdobnikov*
Designed by *V. Solovyov*

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ЭКОНОМИЧЕСКИЕ АСПЕКТЫ
НАУЧНО-ТЕХНИЧЕСКОЙ РЕВОЛЮЦИИ

На английском языке

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English translation © Progress Publishers 1981

Printed in the Union of Soviet Socialist Republics

$X\frac{10701-550}{014(01)-81}81-81$ 03020304

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INTRODUCTION

The scientific and technical revolution (STR) is a multifaceted subject, and much has been written in the Soviet Union and other countries on its various aspects. Scientists, statesmen, military leaders, writers, journalists, teachers and physicians, in fact, almost everyone in the world takes a lively interest in the STR, its potentialities and prospects. That is quite natural because never before in the history of mankind has it had such truly fantastic potentialities both for vast creative effort and global destruction, potentialities for the tremendous enrichment of the material and spiritual content of human life (on a scale which even the boldest flights of fancy had never envisaged), and also the truly apocalyptic possibility of total destruction of all life on the planet Earth.

Atomic and thermonuclear energy, which in the foreseeable future can provide a true abundance of energy, the automation of production, which fundamentally changes the working conditions and the character and content of human labour, the achievements of modern chemistry, which make it possible to produce virtually unlimited quantities of materials with pre-set properties, technological progress, the tremendous opportunities opened up by cybernetics, the exploration of outer space, the broad spectrum of new ways of protecting human health and prolonging man's life, and finally, the rapidly growing means of influencing the processes of organic life, such is the far from complete list of the creative potentialities opened up by the STR.

The Main Document adopted by the International Meeting of Communist and Workers' Parties in 1969 said: "The

scientific and technological revolution offers mankind unprecedented possibilities to remake Nature, to produce immense material wealth and to multiply man's creative capabilities."[1]

However, capitalism tends to block the use of the STR's unrestricted potentialities for the benefit of society as a whole, and converts a large part of scientific discoveries and tremendous material resources for the military purposes in its wasteful use of national wealth. Among the truly apocalyptic characteristics of the devastating potentialities of the same revolution are atomic and thermonuclear weapons, whose stockpiles are sufficient to destroy the whole of mankind and all living things on the Earth; the neutron bomb, the latest "accomplishment" of the US military-industrial complex, which has the "advantage" and "merit" of destroying "only" human beings and all living things, while leaving buildings and structures intact; the means of biological and bacteriological warfare: the global pollution of the biosphere, of its air and water; and the potential dangers of molecular biology (so-called gene engineering).

The capitalist relations of production hamper the use of the STR's positive potentialities, but that does not mean, of course, that the ruling circles of the developed capitalist countries do not seek to make it serve their own purposes. Monopoly capitalism of today has considerable successes in advancing and using the STR. However, only the socialist relations of production make it possible fully to realise the STR's creative potential and to prevent the operation of its destructive potentialities. That is their greatest advantage, as I seek to show in this book.

One of the key problems of the economic competition between the two systems—socialism and capitalism—is the most rapid and efficient realisation of the potentialities of scientific and technical progress. Socialism's victory in this competition will help to consolidate the world socialist system, to raise the well-being of the socialist nations and to strengthen world peace.

In this book, I want to consider the STR—its present and future—from the standpoint of an economist, that is, to

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[1] *International Meeting of Communist and Workers' Parties, Moscow 1969*, Peace and Socialism Publishers, Prague, 1969, p. 19.

present an economic, socio-economic and techno-economic analysis.

Accordingly, I have set myself the following tasks: to present a coherent description of scientific and technical progress and the scientific and technical revolution; to show the origins of the current STR, a logic according to which it is shaped and developed, and in this context to analyse the stages and logic in the development of large-scale machine production, on the one hand, and the content and logic of the STR's development in the natural sciences, on the other; and to consider the STR's impact on the basic elements of modern production (energy, instruments and objects of labour, technology, etc.).

A study of the uniformities governing the origination and trends of development of the STR makes it possible to show the foreseeable prospects of its development with an adequate degree of scientific authenticity. While the STR's future is truly fantastic, I have sought to consider only that which already exists at various stages and that which can be achieved in the near future.

The STR is running its course at a time when the USSR has already built a developed socialist society and is constructing the material and technical basis of communism.

This chief economic task of the Soviet people is determined by the logic of subsequent progress in the development of the mature socialist society in the USSR. Let us recall the monstrous devastation inflicted on the Soviet Union by the war against the nazi aggressors. In 1941 prices, the losses (through direct destruction and plundering of property) inflicted on the economy of the USSR and its individual citizens amounted to 679 billion rubles; in addition, the Soviet state's expenditures on the war against Germany and Japan and its loss of income as a result of the occupation came to 1,890 billion rubles (in the same prices). The greatest loss in the Great Partriotic War was the death of millions of Soviet people: that war cost the Soviet Union over 20 million lives.

Despite the gigantic losses, the powerful creative forces of the socialist system and the Soviet people ensured the rehabilitation of the war-ravaged economy in an exceptionally short period, and then a subsequent rapid and steady growth in social production. By 1950, the pre-war (1940) level of national income and fixed production assets had been sur-

passed, respectively, by 64 per cent and 24 per cent, and industrial output by 72 per cent.

In the following 27 years (from 1950 to 1977), fixed production assets in the economy multiplied 10.4-fold, the national income 7.7-fold, and industrial output 10.9-fold. Energy facilities in the economy increased on a tremendous scale. The generation of electric power went up from 91 billion kwh to 1.15 trillion kwh, oil output from 38 million tons to 546 million tons, gas from 5.8 billion cubic metres to 346 billion cubic metres, and coal from 261 million tons to 722 million tons. The USSR leads the world in ferrous metallurgy: steel output went up from 27 million tons in 1950 to 147 million tons in 1977. A powerful chemical industry has been built up. The USSR also leads the world in the production of mineral fertilizers, whose output went up from 5.5 million tons (in conventional units) to 97 million tons; synthetic resins and plastics, from 67,000 tons to 3.3 million tons; chemical fibres, from 24,000 tons to 1.1 million tons, while engineering and metal-working output has multiplied over 27-fold.

The productivity of social labour in material production went up 9.85-fold over the pre-war (1940) level, and in the past 27 years has multiplied 5.8-fold.

The Soviet Union now has tremendous national wealth worth over 2 trillion rubles, apart from the value of land and forests.

All these results of creative effort made it possible to set the building of the material and technical basis (MTB) of communism as a practical task, which means getting down to creating the material conditions for a gradual transition to the higher phase of the communist formation. This MTB has three main components.

The MTB of material production is the key component of the MTB, and its content consists of the *systemic, socially organised aggregation of the material elements of the productive forces.*

But the MTB of socialism, like that of communism, is not identical with the MTB of material production. The scientific definition of the MTB category must also take into account two other highly important factors.

First, the very much higher and steadily growing *role of science* which is increasingly converted into a direct productive force.

Second, *man's crucial role.* Man is both the subject of progress in science, technology and material production and also the key element of the chief goal of communist production. The CPSU Programme says that the goal of communist production is to provide every member of society with material and cultural values in accordance with his growing requirements, individual needs and preferences.

From this it follows that if the basic tasks of communist construction are to be solved, there is a need to consider and take into account, alongside the chief, leading and crucial sphere of material production, the MTB of two other spheres of social activity: the increasingly important *sphere of science and research and the sphere of the services* (everyday and cultural) *and the spread of knowledge and spiritual values.* The latter sphere has an especially important role to play in the all-round development of man. The development of this sphere helps to increase leisure time and to create the conditions for its creative use, so promoting the growth and enrichment of society's spiritual potential. At the same time, the development of this sphere is a necessary condition for satisfying men's growing requirements in services and spiritual values. The Soviet state's economic policy is firmly directed at steadily building up society's spiritual potential, rapidly developing the sphere of production and the spread of knowledge and spiritual values, and creating the requisite material and technical basis.

The MTB of all these three spheres is evidently a necessary component of the MTB of communism. Ever larger amounts of resources in production and non-production accumulation need to be set aside for shaping each of these.

The building of the MTB of communism in the USSR is a complicated and long-term task calling for echeloned planning and tremendous accumulation resources. The complexity of this task tends markedly to increase because it is being tackled at a time when the socialist state has set itself the raising of the people's living standards as its chief task. Consequently, there is a need to combine over the time scale a stable and rapid growth both of accumulation fund and consumption fund.

The present state and structure of the USSR economy bears the marks of the historical conditions of the Soviet Union's development: the civil war; the industrialisation and collectivisation of agriculture, which proceeded in very hard

conditions; then the war against the nazis and the postwar rehabilitation, the cold war and the arms race imposed on the Soviet Union. There are some outstanding problems in the development and productivity of agriculture; there is some lag in the development of sectors of the infrastructure, which is fraught with losses of the social product (and this is of substantial importance considering the country's territorial specifics); not adequate satisfaction of the Soviet people's requirements in the services: housing, public utilities, retail trade and public catering, everyday services, and so forth.

If all these problems are to be solved, there must be a steady increase of inputs for production and non-production accumulation. The results of the USSR's postwar development show that it has all the conditions for successfully fulfilling all these difficult tasks.

It is natural that realisation of STR advances turns out to be an organic component of the construction of the material and technical basis of communism.

In the CPSU Central Committee Report to the 25th Party Congress, Leonid Brezhnev, General Secretary of the CPSU Central Committee and Chairman of the Presidium of the USSR Supreme Soviet, said: "We Communists proceed from the belief that the scientific and technical revolution acquires a true orientation consistent with the interests of man and society only under socialism. In turn, the end objectives of the social revolution, the building of a communist society, can only be attained on the basis of accelerated scientific and technical progress."[1]

The Soviet people's advance towards the higher stage of the communist formation largely and most importantly depends on its own creative efforts and economic strategy. The CPSU Central Committee's resolution on the 60th anniversary of the October Revolution says: "Socialism is a society of social optimism." But this is an optimism which calls for a level-headed and scientifically grounded consideration of all the complexities and difficulties in solving the forthcoming tasks, and the need and possibility for overcoming various non-antagonistic contradictions.

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[1] *Documents and Resolutions. XXVth Congress of the CPSU*, Moscow, 1976, pp. 56-57.

This optimism was also expressed in the socialist community countries' assessment of their development prospects as they set themselves the task of ensuring stable economic growth rates over the foreseeable future. From 1951 to 1977, industrial output in the socialist countries increased by an average of 9.7 per cent a year, including 9.3 per cent in the USSR. By comparison, the figures for the developed capitalist countries were 4.9 per cent, and 4.2 per cent for the United States. In 1977, the socialist countries turned out over 40 per cent of the world's industrial product. Socialist social production will continue to grow at high rates. The economy of the socialist-community countries does not have to face economic crises like those which regularly rock the capitalist world.

The state of things is quite different in the developed capitalist countries. Many scientists, public figures and statesmen in that part of the world have been broadly discussing the "limits of growth", with many inclining to the need to set such a "limit". Below, when analysing the problem of the future stages of the STR, I shall deal in greater detail with such discussions.

Here is how the present state and the foreseeable future of the economy of developed capitalist countries are described by Alvin Toffler, a well-known US journalist and a former editor of *Fortune* magazine: "...We live in a schizophrenic economy, one that has lost touch with reality. And 'incomprehensible dread' is widespread...

"What we are seeing is the general crisis of industrialism, a crisis that is simultaneously tearing up our energy base. our value systems, our family structures, our institutions, our communicative modes, our sense of space and time, our epistimology as well as our economy. What is happening, no more, no less, is the breakdown of industrial civilization on the planet and the first fragmentary appearance of a wholly new and dramatically different social order; a super-industrial civilization that will be *technological*, but no longer industrial.

"...All the carefully constructed stabilisers," Toffler goes on, "built into advanced economies to prevent a repetition of the 1929 are largely irrelevant." [1]

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[1] Alvin Toffler, *The Future Shock. The Eco-Spasm Report*, Bantam Books, N. Y., 1973, pp. 1, 3.

Toffler writes that the attempts to counter the crisis are now led by economists who are "cleverer and more powerful than in those dark, ignorant, computerless days four decades ago". They use complicated computer models of the economy, input-output coefficients, and other miraculous tools for analyzing and forecasting, and they hold influential government positions, having taught presidents, prime ministers and parliaments how to apply the Keynesian medicines of counter-cyclical spending, taxation and credit control. Taken together it all sounds terribly reassuring—a formidable arsenal of weapons".

Toffler claims that "... a closer look reveals that, like generals, economists are busy fighting the last war. Their stabilisers and tools seem increasingly like a cobwebbed, economic version of the Maginot Line—a mighty fortress with guns pointing in irrelevant directions. Nothing in the history of traditional industrial societies has prepared them (or us) for today's high-speed world of instant communication, Eurodollars, petrodollars, multinational corporations and ganglia-like international banking consortia."[1]

"...The result: wave after wave of malfunctions, and dislocations—postal services, health delivery systems, traffic and transit, police and sanitation services all function spasmodically rather than with the steady, predictable regularity required by the industrial system.

"...Millions are overwhelmed by uncertainty, their identities fragmented, their loyalties confused and cancelling".[2]

"The eco-spasm, or spasmodic economy", is a term used by Toffler to characterise "an economy careening on the brink of disaster, awaiting only the random convergence of certain critical events that have not occurred simultaneously—so far. It is an economy in which powerful upward and downward forces clash like warring armies, in which crises in national economies send out global shock waves, in which former colonial powers and colonies begin to reverse roles, in which systemic breakdowns aggravate economic disorder and economic disorder intensifies and accelerates systemic breakdowns, in which 'random' ecological and military eruptions hammer at the economy from different directions, in which

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[1] *Ibid.*, pp. 4-5.
[2] *Ibid.*, pp. 25, 26.

change piles upon change at faster and faster rates, creating tensions never before experienced in high-technology societies."[1]

In contrast to all this, for all the substantial complexities and outstanding tasks, the USSR economy has been growing steadily, switching systematically to an ever more intensive way of development, which combines regular technical re-equipment and improvement of the organisation of the whole process of production and better use of production resources.

The STR provides socialism and communism with the most adequate technical basis. At the same time socialism and communism provide the STR with the most adequate socio-economic form for its realisation. But the potentialities of the current STR are not realised automatically. They call for purposeful and active management of these processes by society. The chief instruments here are state scientific-and-technical and structural policy, which determines the main lines for improving the proportions and structures of social production, policy in the organisation of social production and the whole mechanism of economic activity.

The task of historic magnitude set by the 24th Congress of the CPSU—"organically to fuse the achievements of the scientific and technical revolution with the advantages of the socialist economic system"[2]—is being tackled through the elaboration and consistent and balanced implementation of the scientifically-grounded economic policy formulated by the Party. This determines the long-term economic strategy for the development of the Soviet economy: the main goals of this development, the sources of growth and the mechanism of economic activity, and also the main lines for improving the proportions of socialist reproduction. The scientific-and-technical and structural policy shows and expresses in concrete terms the guidelines for fulfilling the key socio-economic tasks set by the economic policy of the socialist state.

The USSR is not sealed off from the global problems now facing mankind.

Leonid Brezhnev said in the CPSU Central Committee Report to the 25th Congress that "global problems such as

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[1] *Ibid.*, pp. 51-52.

[2] *24th Congress of the Communist Party of the Soviet Union. Documents*, Moscow, 1971, p. 69.

primary materials and energy, the eradication of the most dangerous and widespread diseases, environmental protection, space exploration and the utilisation of the resources of the World Ocean are already sufficiently important and urgent. In the future they will exercise an increasingly perceptible influence on the life of each nation and on the entire system of international relations. The Soviet Union, like other socialist countries, cannot hold aloof from the solution of these problems which affect the interests of all mankind."[1]

The Soviet Union has been making a positive contribution to the solution of world problems taking into account the experience of world development and the consequences of scientific and technical progress and economic development which have brought the leading capitalist countries to the brink of social and ecological disaster. The organic fusing of the achievements of the STR with the advantages of the socialist economic system is a task of historical importance, while offering the only opportunity for developing the productive forces and production without apprehension and fear, steadily enhancing its efficiency and advancing not to some "limits" or "destruction" but to a social system "with one form of public ownership of the means of production and full social equality of all members of society; under it, the all-round development of people will be accompanied by the growth of the productive forces through continuous progress in science and technology; all the springs of cooperative wealth will flow more abundantly, and the great principle 'From each according to his ability, to each according to his needs' will be implemented..."[2]

Socialism, which has been built and is developing in the USSR, has also taken a great stride forward from the realm of necessity to the realm of freedom. The developed socialist society gives men and women an opportunity to control their own social relations, consciously to use economic and social laws, and so to ensure the socio-economic and technico-economic development of the economy and society as a whole towards communism. The improvement and development of the productive forces and the relations of production

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[1] *Documents and Resolutions. XXVth Congress of the CPSU*, p. 67.

[2] *The Road to Communism*, Moscow, 1962, p. 509.

become an objective of the Party's economic policy, an objective of conscious planning.

In 1876-1878, Engels wrote prophetically in his *Anti-Dühring* that with the transition to socialism "the whole sphere of the conditions of life which environ man, and which have hitherto ruled man, now comes under the domination and control of man, who for the first time becomes the real, conscious lord of nature, because he has now become master of his own social organisation. The laws of his own social action, hitherto standing face to face with man as laws of nature foreign to, and dominating him, will then be used with full understanding, and so mastered by him. Man's own social organisation, hitherto confronting him as a necessity imposed by nature and history, now becomes the result of his own free action. The extraneous objective forces that have hitherto governed history pass under the control of man himself. Only from that time will man himself, with full consciousness, make his own history—only from that time will the social causes set in movement by him have, in the main and in a constantly growing measure, the results intended by him."[1]

In 1923, 45 years later, in an article entitled "How We Should Reorganise the Workers' and Peasants' Inspection" which is a part of his political heritage, Lenin wrote: "We now have an opportunity which rarely occurs in history of ascertaining the period necessary for bringing about radical social changes; we now see clearly *what* can be done in five years, and what requires much more time."[2]

The STR markedly multiplies society's potentialities not only in prognosticating and planning its future, but also in translating these plans into material form.

In saying this, we must be aware of the fact that the future in which vast constructive and destructive potentialities are bound to emerge begins today. Its basic and most large-scale tasks have a long cycle of fulfilment, and we are creating their beginning. The fulfilment of these tasks involves long-term and purposeful activity which includes the allocation of large-scale target-oriented resources and complex programme management.

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[1] Frederick Engels, *Anti-Dühring*, Moscow, 1969, p. 336.
[2] V. I. Lenin, *Collected Works*, Vol. 33, p. 483.

Society's potentialities for fulfilling these tasks have increased immensely.

Socialism and communism alone produce the conditions required for the purposeful solution of the most intricate social and economic problems. The building of a developed socialist society in the USSR has created new requirements, and has simultaneously produced much greater potentialities for meeting these. Leonid Brezhnev says: "Now the situation is changing. Not only do we wish to—for we have always wished it—but we can and must deal simultaneously with a broader set of problems.

"While securing resources for continued economic growth, while technically re-equipping production, and investing enormously in science and education, we must at the same time concentrate more and more energy and means on tasks relating to the improvement of the Soviet people's wellbeing. While breaking through in one sector or another, be it ever so important, we can no longer afford any drawn-out lag in any of the others."[1]

This book contains a detailed examination of the main lines of state scientific and technical policy and the key problems in improving the sectoral structure of material production, with special emphasis on the development and improvement of the structure of engineering, which is the material basis of scientific and technical progress and the technical re-equipment of the whole economy and the non-production sphere. I also analyse some of the problems, which I believe to be the most important ones, in improving the organisation of social production.

It goes without saying that I have necessarily dealt with only some of the broad spectrum of economic problems arising under the current scientific and technical revolution.

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[1] *24th Congress of the CPSU*, p. 48.

CHAPTER ONE

THE CONTENT AND UNIFORMITIES OF SCIENTIFIC AND TECHNICAL PROGRESS

An analysis of the problems arising under the current STR should be started with a definition of the object of analysis, that is, a clarification of the substance of the concepts of scientific and technical progress and scientific and technical revolution.

Before the Second World War, technical progress, expressed in the steady improvement of production technology, and progress in the sciences (especially the natural sciences), characterising the advance in man's cognition of the surrounding world, its structure, the uniformities underlying its development on the macro- and micro-levels long developed on parallel lines, now and then intersecting and interacting with each other, but were not linked organically.

The interconnections and interaction between science and technology began to intensify in the second third and especially the second half of the current century, and their increasing integration was eventually designated in scientific usage by the category "scientific and technical progress". This broadly accepted category tends increasingly to substitute for the earlier prevailing term of "technical progress". "Scientific and technical progress" is a new term reflecting actual processes in the modern world, above all the growing integration of science and technology and the ever more intensive advance of science into the leading position.

Scientific and technical progress is closely bound up both with the productive and with the intellectual activity of men, a reciprocal connection which is realised in their ceaseless interaction. Scientific and technical progress arises

and develops on the basis of this activity and exerts an all-round influence on it in the process of its development. Science itself, like technical solutions, is the product of mankind's intellectual activity. They are integrated and materialised in the advance of the productive forces, in the development and steady improvement of material production.

Scientific and technical progress covers a very broad complex of processes in the life of the developed socialist society. I find that it is appropriate to bring out at least the following of these interconnected processes:

— the elaboration of fundamental problems in natural sciences closely connected with the development of the scientific dialectico-materialist world view;

— rapid progress of every branch of basic science and their ever closer integration with the chief natural, technical and social sciences helping to enhance the transformative role of science in mastering the forces of nature, and its transformation into a direct productive force;

— progress in the social sciences, the growth of their organic interconnection with the natural sciences and mathematics, and with social processes enhancing the level of the scientific grounding of the economic and scientific and technical policies, state planning and management of society's economic and social development as a whole, and also the level and the efficiency of economic activity by every unit of socialist social production;

— the advance of the results of basic research to the point of development and engineering projects; the design, development and production of new and improvement of existing hardware, objects of labour and technology, which are not only capable of ensuring due development of production but also of producing a social effect, that is, of shaping the conditions and character (content) of labour and ecological conditions adequate to the requirements of the developed socialist society;

— creation of a technical basis for transforming labour into a creative process which in itself becomes an important and vital good, a component of the wellbeing of the harmoniously developed man in the socialist and communist society;

— extension of new machinery, materials and production methods to every sphere of social production and the techni-

cal re-equipment of the whole of the economy on that basis;

— the technical re-equipment of the sphere of the services and the dissemination of knowledge and spiritual values on a scale helping to satisfy the Soviet people's growing requirements; creation of the material conditions for a steady increse in leisure time and its most appropriate and creative use for the shaping of the harmoniously developed man of the communist society;

— improvement of the structure of material production and the internal proportions of the main sectoral complexes and individual sectors so as to accelerate scientific and technical progress itself and its realisation in social production; increase in the share of the most progressive industries and lines of production promoting the systematic rise in the level and enrichment of the content of popular wellbeing and ever greater efficiency of social production;

— effective exploration and use of natural resources, notably those which because of the nature of deposits, the difficulties in working these, and the small content of the useful substance would have remained unknown or unused without scientific and technical progress, a "thing in itself" that was never used as a production resource;

— the use of various scientific and technical achievements to improve the organisation of production, labour and management at every level of the economy.

The impact of scientific and technical progress on society's development goes beyond the framework of the immediate process of production. It also has a marked effect on demographic processes by producing highly efficient means of combating disease and preventing the incidence of disease, so helping to prolong life and — most importantly — the period in which men and women are engaged in social activity.

Scientific and technical progress revolutionises the material and technical basis of the services and the dissemination of knowledge and spiritual values, increases the leisure time available to the members of society, immensely multiplies the accessible flow of information and facilitates the efficiency of its perception and processing, so promoting a marked growth in the intellectual potential of society, and in the capabilities and knowledge of men and women, the subjects of progress of science, technology and production. In this

way it enhances the subjective factors which help to make social production more efficient.

Let us note yet another sphere on which scientific and technical progress exerts a very marked influence. This is the shaping of social and individual requirements. Scientific and technical progress, emerging and developing under the influence of society's growing requirements, itself exerts an influence on these requirements, opening up whole spectra of new, unprecedented and frequently requirements unimaginable earlier, stimulating their growth, while creating the material conditions for their satisfaction.

I have tried to formulate the *functional characteristic of the results of scientific and technical progress*, and the set of tasks which are tackled on its basis. What I have said shows that this set is a very broad one and that scientific and technical progress exerts an influence on virtually all the key aspects of vital activity of society.

This naturally raises the question of the interrelation of these two categories: scientific and technical progress and scientific and technical revolution. In this book I intend to give a full-scale definition of the latter, so that I cannot, of course, produce it at the beginning. Here I shall confine myself to stating that the current STR is a complex of processes going forward in science and technology, and correspondingly in production, processes which have been most visibly developed in the second half of the 20th century. Consequently, scientific and technical progress is a broader category, while scientific and technical revolution is a characterisation of its present and foreseeable stages. By analogy, rain is a broader concept than downpour, and wind a broader concept than hurricane.

One has evidently to start by analysing the category of "scientific and technical progress", its structure and connections with the processes of economic development. This will help to determine the methodological approaches and aspects of the analysis of STR processes. At the same time, I feel that it is necessary to analyse the processes going on in the natural sciences and technology, the logic of their development, and also the development of large-scale machine production and the revolutionary changes in its basic elements, so as to provide a basis for defining the material content of STR processes, their material characterisation, socio-economic importance and consequences.

1. THE SYSTEMS APPROACH TO SCIENTIFIC AND TECHNICAL PROGRESS

A consideration of scientific and technical progress with all its internal and external interconnections shows that we are dealing with a complex system, so that the systems approach needs to be used in investigating the problems it tends to produce.

How are we to understand the term "system"? I think that *a system should be seen as a physical (or conceptual) aggregation consisting of interrelated, interdependent and interacting parts and elements.* Every given system is usually a component — a subsystem — of another, broader system.

A system is something that is greater than a mere sum-total of its constituent elements. Science, technology and production are key elements shaping scientific and technical progress. However, all its parts which are included in the whole do not themselves yet constitute a whole. Similarly, workers, machine-tools and tools, materials and technological charts are key elements of production, but do not in themselves constitute production as such. "Structure" and "organisation" are two other closely and organically interrelated categories that need to be taken into account in the process of systems analysis, because it is they that constitute each given system, transforming its isolated elements into a functioning (and so interacting) complex, that is, a system. The latter cannot function or even exist at all unless it has a definite structure and (especially when it comes to a dynamic system) organisation. Although these two concepts are interrelated, structure is more of a static concept and organisation (and control, which is closely connected with it) a dynamic concept.

Structure is one of the key substantive characteristics of any system, reflecting its inner makeup, the correlation and interrelation of its subsystems and elements, the interdependence and subordination of its constituent parts, their functional and linear connections, proportions and the conditions in which they are combined. Only a definite structure transforms the aggregation of elements and subsystems into a *specific system* and determines the possibility of its *preset, purposeful functioning.* The structure of a given system

largely predetermines the nature of its organisation, the latter being regarded as a process.[1]

The specific approach to economic planning ultimately starts from the structure of social requirements (and definite elements of these requirements) and is aimed to shape an adequate structure of social production. Still, structure is not identical with organisation. *Organisation is a process ensuring the functioning of the system with its inherent structure.* Organisation ensures the flow of impulses setting the system in motion and the realisation of its inner interconnections and interactions. It ensures the system's connections with the external world at the input and output terminals, and maintains the system in the state of functioning which is aimed to fulfil the tasks set before it.

Every system, like its component elements, has its specific features, its response to control and controlling action, its forms of possible departure from the ordinary norms of its development, its specific features of responses to diverse effects like interferences and disturbances. All of this together can, in fact, be called the behaviour of systems or subsystems.

Each unit, which is a subject of scientific and technical progress (whether a scientific institution, a technical institute, a laboratory, a production unit or any other object which in practice realises this or that scientific and technical solution) is functioning in the conditions of extremely dynamic development of science and technology, constant changes in the structure of requirements (productive and non-productive), changes in the economic situation, and so on. All of this exerts a multilateral influence on the behaviour of all the parts of the major system. The prognostication and planning, to say nothing of control of such a system, undoubtedly will not be fully effective without an analysis of the structure of the system and the peculiarities of behaviour of each of its components.

Before going on to elucidating the material content of the current STR one has to determine the features and struc-

[1] "Organisation" is a term that can be used in two senses. The first of these is when organisation is taken to mean an organised complex (design, military, production organisation, etc.). In the second sense, organisation is regarded as the process in which this or that complex of organisational measures is realised. Here, "organisation" is used in the second sense.

ture of scientific and technical progress as a system. There are complex and diverse links and interactions between science and technical development projects. The sphere of science and research, like the sphere of technical development projects, may be regarded as complex systems and also as subsystems of a more global system, of scientific and technical progress as a whole.

If we regard science and technical development projects not only as a product of men's intellectual activity but also in terms of the implementation of scientific discoveries and technical projects in the sphere of material production and non-production sphere, scientific and technical progress will appear to be an even more complex system. We shall then also have to analyse its interconnections with the growth and improvement of the material elements of the productive forces. It will also turn out that the physiological and intellectual qualities of men, which are themselves the creators of scientific and technical progress, also tend increasingly to be influenced by it.

Accordingly, there will be a need to consider a broad complex of interconnections of science and technical development projects with production and all its elements, and also with man, the subject of scientific and technical progress.

Having made all these preliminary remarks, let us get down to considering the structure of the object before us. First of all, there is a need to draw a distinction between two of its component parts: research and technical development projects[1] (R & D) which are the two subsystems of the first order.

Science and technical solutions are the product of men's intellectual activity. *Science* is all-round research and a complex of scientific discoveries which have been brought up to a structural characteristic reflecting a definite aggregation of objects and phenomena active in the real world, in nature and society, and determining the uniformities governing the formation and development of these objects and phenomena.

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[1] When we speak of technical development projects (D), we mean all the applied development involving the practical use of the results of research in material production and beyond it. D may produce not only machinery and method for the production of material goods, but also concepts and methods which do not directly yield material products.

By *technical development projects* is meant the complex of engineering solutions based on the use of the results of research and making possible the construction and functioning of definite elements of production: machinery, objects of labour and production techniques (methods), and the creation of the goods and services required by society. The production and final consumption (productive and non-productive) of the goods produced as a result of scientific and technical progress may be most closely connected with the latter, but are, nevertheless, not its component parts. These are special socio-economic systems with their own extensive range of ties.

Each of these two subsystems of the first order has a complex inner structure (that is, it includes a number of subsystems of second, third, etc. orders) and is accordingly characterised by an intricate complex of external and internal, direct and feed-back connections.

Without giving the details of all the subsystems, let me list merely the subsystems of the second order:

I. *Research*

1. Mathematics
2. Physics
3. Mechanics, cybernetics and control processes
4. Chemistry
5. Biology and allied sciences
6. Medicine
7. Earth sciences
8. Social sciences

II. *Technical and other applied development projects*

1. The energy basis of production
2. Instruments of labour
3. Means of transportation and movement
4. Devices for data processing
5. Means of protection of the environment
6. Means of communication
7. Objects of labour
8. Techniques
9. Organisation of production and labour (industrial engineering)
10. Control

The complex inner structure of each of these subsystems of the second order will be seen from the fact that physics contains (as subsystems of the third order) the following:

1. Atomic and nuclear physics
2. Plasma physics
3. Quantum physics
4. Solid-state physics, etc.

For its part, solid-state physics, for instance, has a number of important branches, i.e., subsystems of the fourth order. The same multiplicity will be found in the complex of chemical, biological and other sciences.

As I intend to show in subsequent chapters, each second-order subsystem within D, like an instrument of labour, for instance, also has complex inner hierarchical structure.

When considering the Technical and Other Applied Development Projects subsystem, one should specially look at the three latter subgroups: techniques; organisation of production and labour; and control. While, in contrast to the first six subgroups, these are not direct material elements of modern production, they have nevertheless become its immediate key elements, having an ever more active role to play and exerting a highly radical influence on the instruments of labour and other material elements of production.

This is most clearly seen in techniques. At the end of the 19th century, this was almost entirely determined by the product of labour, i.e., the kind of article that had to be produced, on the one hand, and the object and instrument of labour, on the other. Subsequently, techniques became increasingly multivariant, and today it is perhaps techniques that is the basic point of application of the results of research. The penetration of science into production increasingly occurs through techniques, and through the latter it exerts an influence on the instruments of labour. Thus, techniques becomes an active element of the production process.

> As an example, take the method of the continuous pouring of steel, which has been developed with the advances in solid-state physics. It eliminates gigantic machinery like blooming mills. Advances in the methods of welding have gradually helped to eliminate giant facing lathes, and so on and so forth.

The multivariant and the growing multioperational nature of techniques naturally enhances the role and importance of the organisation of production and control, which are designed to select the best variants and realise these in the process of production. It goes without saying that organisational and management decisions exert a considerable influence on the material elements of production and especially on their use and the efficiency of their functioning.

Consequently, within the limits of each of the two first-order subsystems — R & D — there are numerous and highly complex direct and feed-back connections.

> One need merely refer to the role of mathematics in the development of all the natural (and lately also the social) sciences, of physics and chemistry in the development of the biological sciences, and of cybernetics in the development of all the sciences; there is also the ever more tangible impact of the social sciences—philosophy, political economy and sociology—on the development of the natural sciences and even on mathematics. Indeed, more and more new frontier sciences tend to arise at the junctures of the traditional scientific disciplines.

As I have already shown, there are also internal connections in D between the individual functional elements of production. The instruments and objects of labour exert a diverse influence on production methods. With the emergence of synthetic materials with pre-set properties, the objects of labour also begin to play an active role, determining changes in technology and frequently stimulating radical changes in the instruments of labour. The instruments of labour, the objects of labour, techniques, the organisation of production and job and management are influenced by a data processing, the methods used in decision-making, the means of transport and communication facilities.

Mathematics, electronics, automation and cybernetics, the biological sciences, the study of the brain and higher nervous activity, the economic sciences and sociology directly shape and improve the organisation and control of production.

One could take a somewhat different approach in defining the structure of scientific and technical progress.

Scientific and technical progress is essentially a purely dynamic phenomenon. If we regard it as a system moving in time and, accordingly, its time structure and origins, we shall discover a deeply echeloned complex which includes, at least, the following elements: first, general education and special secondary and higher education; second, complexes of research (in the basic and applied sciences) and technological design institutes, together with their experimental and engineering facilities; third, material production proper, in which scientific and technical progress is materialised; and fourth, the sphere of production and non-production consumption in which the new technology is used in accordance with their ultimate purpose.

The first echelons consist of the subjects of scientific and technical progress, the personnel working in science, technology and production. In the middle echelons, intellectual activity by this personnel results in scientific discoveries and technical solutions, and finally, in the last echelons (according to our scheme) scientific and technical progress is realised and applied in practice.

One of the key advantages of the socialist economy is the possibility of state planning and financing and, accordingly, of the proportional and balanced development of all the above-mentioned elements in the progress of science and technology, and also the possibility of shaping a balanced sectoral structure of material production and the inner structure of its basic subdivisions, on which largely depend the pace of development and especially realisation of scientific and technical progress.

Complex direct and feed-back connections exist between the above-mentioned echelons of scientific and technical progress. Each preceding element creates the prerequisites—material and spiritual—for the development of subsequent elements, and above all for steady progress, scientific discoveries and technical solutions. At the same time, each science and each industry have their own inner logic which largely determines the trends of their development.

Thus, the nature of general and, in particular, of special education must reflect the perspectives of science and technology and the changing demands which these will naturally make in the immediate and long-term perspective on the training of personnel and their specialisation. This does not rule out the need for periodic extension courses and retraining for specialists at every level, but the basis of gen-

eral and special education needs to be constantly analysed with an eye to the steadily changing trends in scientific and technical development.

Let us note that the effort here is inadequate, despite the fact that the workers of the 1990s and the year 2000 are already going through various stages of education. And, of course, there is a need constantly to "verify" the nature of the education with the requirements these cadres will have to face in the foreseeable future. Consequently, in shaping the first echelons one has to start from a definite conception of technical policy, and also from a conception how this policy exerts an influence on the structure and nature of the labour functions and, accordingly, on the structure and specialisation of the personnel.

As STR accomplishments are applied in production there is evidently a tangible change in the nature and content of the skills of workers at every level. New trades emerge while the traditional ones are altered. At the same time, it is safe to say that with the progress and complexification of technology the requirements on the skills of workers grow. This entails a combination of growing requirements on the level and scope of general educational training with the need to adapt fairly rapidly to special activities, which, for their part, tend to change their content relatively fast. In these conditions, extensive general education must go hand in hand with a virtually continuous process of improvement and raising of skills and a retraining of personnel.

Such are the basic structural characteristics of scientific and technical progress and the main internal interconnections of its constituent subsystems.

2. EXTERNAL TIES OF SCIENTIFIC AND TECHNICAL PROGRESS

These ties are exceptionally extensive and important, especially with the economy. That is why the prognostication and planning of scientific and technical progress may be justly regarded as the most important starting point in the prognostication and planning of society's economic development.

Let us look at the main lines of connection and interaction between scientific and technical progress and the processes of economic growth and development in society.

I believe that there are at least three main lines.

The first is *the immediate influence of scientific and technical progress on the development of the productive forces, on the dynamic and structure of social production.* By raising the technical level and efficiency of the traditional elements of production and creating new and more perfect ones, scientific and technical progress makes for a growth in the volume of material production and for considerable changes in its structure. It also induces substantial changes in the structure of production and individual consumption. By shaping new interconnections between industries and changing the traditional ones and the flows of material inputs, it has an influence on shaping the structure of the final product, i.e., on the balance between production and non-production consumption and accumulation.

The second line is that *scientific and technical progress has a considerable influence on almost all the exogenous factors of economic growth*, like the dynamic of the population and manpower, the volume and structure of available natural resources, and so on. In present-day conditions, scientific and technical progress is increasingly becoming an integral part of all these basic conditions and factors of economic growth and development. In effect, the scientific and technical achievements provided the conditions for medicine to reduce mortality and to some extent promoted the "demographic explosion". They also largely determine the steady growth and changing structure of the population's requirements. Or, say, natural resources. So long as they have not been prospected and extracted, they are in a sense a "thing in itself". Scientific and technical progress, and the STR in particular, help to explore mineral deposits of which men had no knowledge before using the equipment of geological survey with the latest technical facilities, like ultrasonics and radar, mathematical computer-based modelling, modern optical devices, artificial satellites and spaceships. Modern scientific achievements make it possible to extract and dress natural resources which had earlier been regarded as useless.

The third line consists to some extent of *indirect and mediated connections between scientific and technical progress and economic growth.* The fact is that the key trends in the progress of science and technology result in a whole complex of qualitative changes in man, society's chief productive force.

Biology, genetics, physiology and medicine, biological chemistry and pharmacology have exerted and will continue to exert a growing influence on man's physiological and mental state. Computers and communications facilities tend radically to change the system of education, the forms, volume and methods in which man receives internal and international information. The importance of these changes is quite comparable with the changes produced by the invention of printing.

Whereas the facilities of large-scale machine production, beginning from the industrial revolution characterised by Marx, up until the recent past, and largely even today, immeasurably enhanced man's physical capabilities and potentialities, the means of communication and data processing being developed on the basis of the STR tend sharply to enhance man's intellectual potentialities.

But man is not only the subject of production. He is also the subject of R & D. The physical, intellectual and moral improvement of men is a powerful catalyst of scientific and technical progress. It will be easily realised that these processes will exert a substantial influence on the quantitative and qualitative changes in the economy.

The quantitative interpretation of the three lines of scientific and technical progress and their respective reflection in models and plans for economic development is a complicated methodological problem.

The most difficult task, both in methodological and information terms, is to determine the quantitative parameters of the interconnections and the interdependencies in this chain: scientific and technical progress—production—man.

The investigation of social production as a large and complex system evidently requires not only an analysis of the processes which determine changes in technology, but also a parallel analysis of the processes which are connected with the changes and progress in man himself, and also of their interaction. Primary importance attaches to the analysis of the changes in the nature of labour arising as a result of technological progress, which determine the radical social shifts in the structure of society.

The point is that the development of man, the chief productive force, and the impact of these changes on the course and pace of scientific and technical progress, on the factors and processes of economic development have usually been

very rarely and inadequately appreciated and reckoned with. But these impacts and interactions are perfectly obvious. Here are their main lines:

1. The influence of social, scientific and technical progress on man's living and working span, and on his physical and intellectual capacity.

2. The influence of scientific and technical progress on the length of time it takes a worker to acquire a professional skill with the rapid changes in technology.

3. The influence of the changes in man's creative capacity on the acceleration of scientific and technical progress.

I think that any economic study of scientific and technical progress must simultaneously be a socio-economic study, at least from the standpoint of taking into account the capabilities and potentialities of man as the active factor in scientific and technical progress and economic development.

In principle, the impact of the first two lines lends itself most simply to a quantitative interpretation. The first of these, in effect, results in an increase in productive manpower resources. It is a methodologically soluble problem to calculate the additional manpower resources made available in establishing losses arising from illness, and to determine the age interval of the highest labour productivity and measures designed to lengthen it. The second line accelerates the attainment of high skill standards and also a rise in their level, so that, given the relevant information, it is also possible to determine the measure of related structural shifts in the labour productivity.

The importance of taking into account these changes tends to increase because the training of specialists and of skilled workers turns out to be an ever longer process.

But it is a highly complicated methodological problem to produce a quantitative evaluation of the influence of man's growing creative capabilities on the pace of scientific and technical progress and on the level and efficiency of production, a problem whose solution entails special sociological studies, collection of sizable amounts of information, points evaluations, etc.

There is a need specially to consider the interconnections between scientific and technical progress (and the STR in particular) and production which are characteristic for the present and the foreseeable periods in the development of society.

In the second half of the 20th century, R & D are being intensively industrialised.

Tremendous material and manpower resources—an ever growing share of the national income—are going into research, development and engineering. Nowadays, the basic sciences increasingly require complex, powerful and expensive technical equipment. Academician L. A. Artsimovich, a leading Soviet physicist, wrote: "With each year, physicists have to make their way through ever thicker layers of ever harder rock. Everything that has lain on the surface has long since been discovered, studied and understood. The exploration and comprehension of new uniformities in the sphere of elementary particles relating to distances approaching 10^{-15} cm or in the world of recently discovered superstellar objects billions of light years away require extreme tension on the part of physicists and astrophysicists and regular technical re-equipment of laboratories as experimental facilities acquire ever greater dimensions and truly astronomical costs... One could say that in the past several years there has been in physics a steady and extremely rapid increase in the cost of scientific discoveries (that is, of the material and intellectual inputs incidental to each of these)".[1]

> An official NASA publication said that the Apollo programme is estimated to have cost $20-30 billion; it took $400-700 million to develop the IBM-360 generation of computers on hard logic circuits; the development of the Boeing-707 commercial jet cost roughly $700 million; about $2 billion was put into the development of fast-neutron nuclear reactors, and so on.
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> In the USSR, direct appropriations for science from the state budget and other sources in 1965 came to 6.9 billion rubles, in 1970, to 11.7 billion, and in 1977, to 18.3 billion.

The vast proportions of the specific inputs required for advancing R & D also mean that *present-day scientific and technical progress, developing in accordance with its own logic, tends increasingly to be influenced by the scientific and technical policy of the state, and in this sense is controlable and even dependent.* From this it follows that the financing of science

[1] *Novy Mir*, No. 1, 1967, p. 198.

and technology, and the provision of their material facilities call for considering long-term strategic perspectives, i.e., long-term prognostications of their development, which, for their part, become an instrument of active influence on the course and direction of scientific and technical progress.

Consequently, *scientific and technical progress being, on the one hand, a very important factor of economic development, is, on the other, increasingly dependent on the latter.* It would be an oversimplification to assert that the direction of scientific and technical development is straightforwardly predetermined by the volume of material resources allocated for these purposes. But it is incontestable that the general scope of such progress is increasingly determined by the dynamic of material inputs into this sphere. The latter, for their part, are determined by the relation between accumulation and consumption, that is, by the basic proportions of reproduction. Consequently, the prognostication of economic growth in which the results of scientific and technical progress are regarded as starting factors or conditions has to be preceded by the elaboration of some preliminary model which helps to determine the approximate scale of the resources society is capable of allocating for the development and acceleration of scientific and technical progress.

3. SCIENTIFIC AND TECHNICAL PROGRESS. EFFICIENCY AND PROPORTIONS OF SOCIALIST REPRODUCTION

There are close and multilateral, direct and feed-back connections between scientific and technical progress, the efficiency of production and the basic proportions of socialist reproduction. What is the mechanism of these ties and interactions?

The usual approach in describing scientific and technical progress is to show its directions, and to classify these according to the branches of science or their technical content: electrification and atomic energy, atomic engineering, chemicalisation, automation, computerisation, beam engineering (quantum generators), etc. Such an approach and classification are well-justified and necessary.

But it is another matter when we want to analyse the impact of scientific and technical progress on economic results, on the efficiency of production.

By improving all the elements of production, scientific and technical progress is the condition for saving every type of inputs: living labour, materials, and fixed assets.

The improvement in the instruments of labour enhances their productivity, i.e., helps to increase output per unit of time and, consequently, to reduce the assets-output ratio and especially that of the active part of the assets; mechanisation and automation help to save the inputs of living labour connected with the use of the instruments of labour. The outcome is a growth of labour productivity and an increase in the output-assets ratio.

The introduction of more progressive (especially synthetic) materials increases the output per unit of primary raw and other materials, i.e., helps to reduce the material-intensiveness of production. Because the new materials lend themselves more easily to treatment, the inputs of labour and assets into the processing operation are reduced, and this helps to lower the assets-output ratio and labour intensiveness.

The introduction of new and more progressive production methods improves the use and output indicators for equipment, makes for more rational use of primary materials, improves quality and gives the final product longer life, i.e., improves the use of all the elements of production and, accordingly, reduces all the elements of the inputs.

Improvements in the organisation of production, organisation of labour and control (management) produce the same results.

Each of these lines may have an influence on different elements of the inputs. Thus, for instance, electrification of production processes can help to save living labour (when labour processes are mechanised), or may help to save on materials, where some electrotechnology hardens the material, improves its quality, length of life, etc. The use of chemicals may accelerate some production processes (oxygen blast in metallurgy, catalyst in chemistry) and with the same or relatively smaller inputs of labour may help to increase output, i.e., to increase the effectiveness of equipment, the output-assets ratio and labour productivity. It tends also to ensure optimal use of primary raw materials, and

improve their quality, so reducing the material-intensiveness of production.

Consequently, if one is to characterise the lines of scientific and technical progress from the standpoint of their impact on the economic results of socialist production and its efficiency, one has to classify these lines according to their impact on the elements of production inputs: on labour-intensiveness, material-intensiveness and assets-intensiveness.

Such an economic classification is especially necessary in studying the influence of scientific and technical progress on the basic proportions of reproduction. That is so because the various lines along which the efficiency of production tends to change, i.e., changes in the inputs of labour, materials and production assets, are most closely connected and exert an active, even if different, influence on the basic proportions of reproduction.

The most important proportions of expanded socialist reproduction are the correlation between the two departments of social production—production of the means of production and production of the consumer goods, the share of production accumulation (the resources allocated for expanding production, formation of production reserves, and research), and the share of consumption in the national income.

What is the mechanism by means of which scientific and technical progress acts on the proportions of reproduction? By raising the effectiveness of equipment and labour productivity, and ensuring saving of raw and other materials, scientific and technical progress determines the changes in the inputs of basic production resources per output unit, i.e., changes in the labour-intensiveness, material-intensiveness and assets-intensiveness of production. This makes for a corresponding change in the volume and dynamic of requirements of material production in labour resources and the means of production. Let us recall that the means and objects of labour are the products of Department-I of social production. Consequently, scientific and technical progress determines the necessary volume and dynamic of this Department, and so also the share of the national income which needs to be allocated for expanding the production of the means of production, i.e., the share of production accumulation. A change in the share of production accumulation determines changes in the share of the population's consumption fund.

By relatively reducing the requirements in the means of production, scientific and technical progress also exerts an influence on the structure of the use of the production accumulation fund. The higher the inputs of the means of labour and materials for a given volume of final product, the greater the part of the means of production (and accordingly of the production accumulation fund) that society will be forced to allocate for increasing the production of the means of production; in other words, in those conditions, Department-I—production of the means of production—tends largely to cater for itself. But on this also depends the part of the means of production that have been made and that can be used in the development and expansion of the production of the consumer goods. The latter, for its part, determines the volume and dynamic of the consumption fund.

Consequently, the more perfect the means of production and the more fully and efficiently they are used, the faster the growth of the consumption fund. There is here a very direct connection. That is why under socialism the working people's concern for the technical level and efficiency of production is also concern for improving their own wellbeing.

So, *there is a close interconnection between the elements of the chain: the lines of technical progress—efficiency of production—basic proportions of reproduction.* From this it follows that the socialist state's technical policy can become an ever more active factor in boosting the efficiency of production and improving the proportions of reproduction.

At the same time, *the scale of the feed-back connections tends to become ever more impressive as the efficiency of production and the proportions of reproduction influence the pace of scientific and technical progress.*

First of all, the growing efficiency of production helps to increase the volume of production accumulations[1] and, on that basis, the growth of the means and resources allocated for the development of R & D.

The growing efficiency of production includes the fuller (intensive and extensive) use of equipment and, consequently, accelerates its payback period and, accordingly, brings

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[1] I emphasise "volume" but not the rate or share of production accumulation in the national income because, I think, high efficiency of production can ensure a simultaneous growth of the consumption fund and the production accumulation fund.

on the economically justified deadlines for its replacement by new and more sophisticated equipment.

> If we assume, for instance, that the depreciation rates are calculated on the basis of a 15-year period of service with a 2.0-shift ratio, the equipment will be fully depreciated in 20 years, instead of 15, if the actual shift ratio is 1.5. This means that the deadline for installing new hardware, i.e., the period for realising scientific and technical progress in production, will be put off by five years. If society refuses to accept this, and replaces the equipment within 15 years, it will be forced to incur a loss equal to 25 per cent of the full cost of the replaced equipment.

Under socialism, the growing efficiency of production makes it possible to increase the consumption fund and to raise the people's wellbeing, and consequently also the cultural standards of the working people, which are the subjects, the creators of scientific and technical progress. This naturally acts as an accelerator in the progress of science and technology.

Finally, the growing efficiency of production implies an improvement in the organisation of production and the use of modern scientific methods of planning and management at every level, which is also an essential condition for accelerating scientific and technical progress.

4. SOME SOCIO-ECONOMIC CONSEQUENCES OF SCIENTIFIC AND TECHNICAL PROGRESS UNDER SOCIALISM AND CAPITALISM

Scientific and technical progress as a whole, and the STR in particular, are closely connected with society's socio-economic development, and with the state and dynamics of the relations of production.

The STR is now in progress both in the socialist and in the capitalist countries, and it is highly important, therefore, to analyse the influence of each of the social systems on the development and the socio-economic consequences of scientific and technical progress and the STR, and also the impact of the latter on the fortunes of each of the social formations.

In considering the socialist system and its interaction with the STR, one should note at least the following of its characteristic features:

— the domination of social property in the means of production and the absence, in consequence, of any contradictions between the social character of production and the private form of appropriation;

— the balanced organisation of the whole process of expanded socialist reproduction;

— the absence of exploitation and a fundamentally different goal in production than the one under capitalism, namely, the ever fuller satisfaction of the people's material and cultural requirements;

— practice of the principle of payment in accordance with the quantity and quality of work;

— involvement of millions of working people in culture, science and knowledge, a steady rise in the cultural standards of the whole population, the broad spread of technical knowledge, and in a remoter future—under communism—elimination of any essential distinctions between mental and manual work, and of other social distinctions between men, which is one of the key goals of society;

— the preservation of commodity-money relations and commodity-money forms of connection between the units of the economy, production collectives, etc., under a planned economy and with socialist property in the means of production;

— harmony of the vital interests of society, production collectives and every member of society.

Among the specific features and advantages of the socialist economic system is the elimination—in the early 1930s—of unemployment and, for that reason, freedom from any fear of unemployment among the working people of the USSR. Because most of the property in the USSR belongs to the whole people (and in agriculture, there is large-scale collective-farm and cooperative property) there is no rivalry, and no enterprise can go bankrupt. In the USSR, the heads of enterprises are not faced with the danger of going bankrupt. These obvious social advantages of the Soviet system also eliminate automatic incentives for speeding up technical progress like competition and the danger of going bankrupt. Accordingly, there arises the complicated task of setting up an economic mechanism that would shape the material and moral incentives for accelerated develop-

ment and introduction of technical progress that would simultaneously absorb the Soviet people's tremendous social gains.

The countries of victorious socialism face the task of solving one of the most important problems in further developing their productive forces and successfully fulfilling the socio-economic tasks of the socialist society, the problem of replacing the relentless incentives arising from rivalry and the existence of a chronic reserve labour by a system of incentives that would be equivalent and even more effective but that would safeguard the great human rights written into the Constitution of the USSR, above all, the right to work, incentives ensuring the exercise of one of the chief principles of socialism: "From each according to his abilities, to each according to his work."

These features determine a number of peculiarities of the development of technical progress and its social consequences and the methods used in influencing and controlling it.

Socialism creates the possibility for centralised state planning and financing of all the echelons of scientific and technical progress: extensive development of general education and culture in society, training of scientific, engineering and technical personnel and skilled workers, establishment of a network of research, design, development and engineering institutions, development of experimental facilities for applied and basic research, material backup and balanced realisation of progressive technical policies, etc.

The following data show the realisation of these potentialities in the postwar period:

	Number of persons (ths.) graduated from	
	secondary (general and special) education schools	higher educational establishments
1918-1940	3,829	1,208
1941-1950	3,652	954
1956-1960	13,738	2,619
1961-1970	22,853	4,350
1971-1977	28,745	4,952

Only in the past 17 years, 51.6 million persons in the USSR received a full secondary education, 9.3 million, a higher education, and 15.0 million, a secondary special education. Such is the scale of the first echelon of scientific and technical progress—the training of cadres of educated men and women, the subjects of progress in science, technology and production.

The following data give an idea of the grand scale of the achievements of the socialist system. The number of persons enrolled in higher schools increased from 127,000 in the pre-revolutionary 1914/15 academic year to 5.0 million in the 1977/78 academic year; in secondary special schools, from 54,000 to 4.7 million; and in primary, incomplete secondary and secondary schools, from 9.7 million to 45.4 million.

The number of scientific personnel (including teachers and researchers at higher schools) increased from 162,500 in 1950 to 1,262,000 in 1977. In the same period, the number of persons engaged in scientific and scientific-service establishments went up from 714,000 to 3,970,000. The expenditures on science went up from 1 billion rubles in 1950 to 3.9 billion in 1960, 11.7 billion in 1970, and 18.3 billion in 1977, or 4.5 per cent of the USSR national income.

At every stage of communist construction, the socialist state takes account of the attained level of economic development, science and technology and the emerging requirements of society, and takes steps to shape a balanced sectoral structure in material production, giving preference to the development of the high technology industries and lines of production which determine rapid progress in the basic and applied sciences, acceleration of technical progress and the growth of efficiency in social production.

From 1950 to 1977, industrial output multiplied 11.05-fold, while generation of electric energy increased 15.6-fold, output in engineering and metal-working, 27.4-fold, and in the chemical and petrochemical industries, 26-fold. Advanced sectors of engineering like the making of fine instruments and computers have been developing at a sharply stepped up pace. From 1950 to 1977, their output increased, respectively, 66 times and 5,047 times, including from 1950 to 1965, respectively, 16.1 and 122.5 times, and from 1965 to 1977, 4.1 and 41.2 times, reaching in 1977 4.1 billion and 2.8 billion rubles a year, respectively.

Socialist production and scientific and technical progress are geared to the attainment of the main goal: improvement of the people's wellbeing and fulfilment of the basic social tasks of communist construction. That is why the contradictions which arise in the realisation of scientific and technical achievements are not antagonistic, as they so palpably are in the capitalist countries.

Even under socialism, the effort to realise in production and in the socio-economic sphere the potentialities of the STR gives rise to the highly complicated problem of the interrelation between the three interconnected complexes:

—STR-induced R & D, and the potentialities they create for improving every element of material production and the non-production sphere;

—the logic and momentum of the development of large-scale machine production, above all, of its existing production facilities;

—the socio-economic consequences of the STR, which are closely bound up with the chief social goals and tasks of the given social system.

Each of these three complexes, for all their organic interconnection, has its own logic of development, and their interaction in time is fairly complicated.

First of all, the nature of each of these determines the time sequence. A scientific discovery is followed by a technical solution, after which the potentialities created by the STR may be gradually realised in material production. Thus, the second complex can develop only after the first.

Apart from this, substantial distinctions may exist within the structure of the first two complexes. For all their interdependence, the development of science and technology and of material production are subordinate to their own inner logic. That is why the structure and trends of scientific discoveries and technical solutions not always coincide in a straightforward manner with the direction in which material production develops. This situation also produces substantial distinctions between simultaneously running stages of the STR and stages in the development of large-scale machine production.

The STR's ideological achievements apart, its economic effect and social potentialities may become manifest only after the new technological solutions are broadly applied

in material production and the non-production sphere, i.e., after the second complex is realised.

But one could say that this is an ideal picture. The use of the STR's results in production and realisation of its social consequences does not run along a free and smooth highway. It inevitably and naturally comes up against impediments which are organic to the nature of each of these complexes. This is expressed above all in the fact that with the close functional interconnections between stages of the STR and the simultaneously running stages of the development of material production, there are considerable time gaps, which is only a different and wider expression of the problem of realising and applying scientific and technical achievements to production.

The first cause of such time gaps springs from the existence of the production facilities created earlier and reflecting previous stages in technical development of the production apparatus, a vast inertial mass of which largely determines the main characteristics of the corresponding stage in the development of material production.

In early 1978, fixed assets in the USSR economy were valued at 934 billion rubles. The annual output of the elements of fixed assets is many times smaller than the assets themselves, so that there is a need for sufficiently long periods to effect a truly radical renewal of the production apparatus. Thus, in the Soviet Union the fleet of metal-cutting machine-tools is over 20 times larger than their annual output. The inertial processes are also intensified by the fact that a sizable part of the production apparatus continues to turn out traditional machinery, so maintaining a great share of it in the years ahead. This determines a considerable gap between the potentialities of the given stage in the STR and the technical level of the production apparatus.

The second cause springs from the economic efficiency of new technical solutions and the efficiency of material production itself. The new technologies produced by the STR must themselves go through a number of stages of "maturing" so as to achieve the necessary economic effect by offsetting the initial inputs into R & D. But the problem also consists in the fact that a sizable part of the production apparatus (especially the younger part) turns out to be far from fully depreciated. Accordingly, society is forced either

to postpone the introduction of new technology and to await the completion of depreciation (and recoupment) or to incur the losses arising from the pre-scheduled removal of technology, or, finally, to move the threshold of efficiency to the point at which the effect would compensate for the losses.

The third cause springs from the considerable time gaps between the various stages of scientific and technical progress: from the scientific discovery to the realisation of its results in production. These time gaps are of objective nature, and are also compounded by many technical and organisational factors. Apart from the constraints arising from the available resources, notably investment resources, in some concrete conditions such time gaps may be produced by prolonged periods of construction and mastering of new production facilities.

In the 20th century, especially in the second half of it, the renewal of the key elements of production has been sharply accelerated. When these amount to decades, we complain about their length and frequently fail to recall that not very long ago similar shifts lasted for centuries.

Scientific discovery—technical solution—pilot production—first batch—application in production constitute the interconnected stages of scientific and technical progress. One of the main goals of the socialist state's economic, technical and structural policy is to reduce to the utmost the time gaps between them. This requires consistent solution of the most important strategic problems of the single state technical policy: the machinery and the technological solutions adopted must be up to the level of achievements (solved in scientific and technical terms) and the potentialities of the STR, naturally, with an eye to the economic effectiveness. Otherwise, serious obstacles will arise in the way of realising the potentialities of the current STR.

Substantial problems also arise in the realisation of the third complex, the STR's socio-economic consequences. Their realisation goes under definite social conditions, and on the basis of definite relations of production, which also determine the social nature of the STR's consequences. Although socialism does on the whole create favourable conditions for realising the STR's potentialities, even in the socialist society realisation of the STR's social effect does not at all occur automatically. It requires persevering

and consistent social orientation of all technical and many scientific solutions. The social effect is a benefit for the people, for which the socialist society is prepared to pay in the form of resource allocation. This refers to the content of labour itself, and so also to the corresponding features of technology, and to the technical equipment of the sphere shaping the people's material and cultural standards.

However, for all their undoubted difficulties, these problems can be solved through the balanced activity of planning and economic bodies.

Let us recall the complicated and difficult ecological consequences produced by the STR in the developed capitalist countries. Soil erosion, pollution of water and air, a global threat to the World Ocean and all living beings in it, all these are facts characterising these processes as reported in the world press. The attempts by some governments to safeguard the national interests against the damage being inflicted by the self-seeking interests of the monopolies do not always yield the desired results.

The socialist countries naturally face environmental problems as well. The advantages of the socialist mode of production make it possible to solve this problem purposefully, on the scale of society as a whole, and for its benefit. In the USSR and other socialist community countries, protection of the environment is state policy.

In the economic competition with capitalism, the USSR is in a position not to repeat the stages of technical development which in the developed capitalist countries in practice resulted in negative ecological consequences, and the development of motor transport provides a fitting example.

The USSR decided broadly to develop automobile and other types of public transport, such as buses and coaches, trolleybuses, tramcars and the underground. The massive character of these types of transport, the low fares (it costs 3 kopeks to travel any distance by tramcar, 4 kopeks by trolley, and 5 kopeks by metro and urban bus) make for their extensive use by the population.

Here are some data on the development of public transport in the USSR.

The carriage of passengers by these types of public transport increased from 8.5 billion persons in 1940, to 7.8 billion in 1950, 23.3 billion in 1960, 43.7 billion in 1970 and 57.8 billion in 1976. These highly impressive totals

Types of public transport	1940	1950	1960	1970	1976
Buses					
Passengers carried, bln.					
1. urban				20.5	27.8
2. suburban	0.6	1.0	10.8	5.4	8.1
3. interurban		0.05	0.53	1.5	1.95
Total	0.6	1.05	11.3	27.3	37.9
Urban rolling stock					
1. vehicles, ths.					
a) tramcars	11.4	10.7	17.1	22.1	20.2
b) trolleys	0.8	1.8	5.4	15.8	21.3
c) metrocars	0.3	0.5	1.2	2.5	3.7
Total	12.5	13.0	23.7	40.4	45.7
2. Passengers carried, mln.					
a) by tram	7,283	5,157	7,842	7,962	8,343
b) by trolley	294	945	3,055	6,122	8,345
c) by metro	377	629	1,148	2,294	3,229
Total	7,954	6,731	12,045	16,378	19,917

and pace of growth will evidently enable the USSR in the foreseeable future not to increase the number of petrol-driven cars to 125 million, the US figure, and to switch more swiftly to the making of electrocars.

The organic connection between the STR and socialism is expressed in the fact that *socialism is capable of making extensive use of the whole spectrum of the STR's potentialities.* Here, scientific and technical progress not only multiplies human requirements but also makes it possible more fully to satisfy them. Socialism opens up before mankind the prospect which Marx called the "humanisation of requirements"; science and technology exert an influence on the shaping of the socialist way of life which is characterised not only by a steady growth of material living standards but also by high and rising levels in man's spiritual and intellectual world. Under socialism, "the scientific, technical and cultural revolutions are interlinked organically. This makes it possible to achieve a new level in the development of revolutionary practice as a process in which the trans-

formation of the world and the change of man himself coincide. This level of practice will help to gain a deeper understanding of the earlier stages in society's development, age-old problems and the contradictions and limitations of the capitalist social formation."[1]

In the socialist society, scientific and technical progress is the crucial factor for attaining the main and ultimate goal of social progress, the building of a communist society.

Over the long term, the inexhaustible potentialities for the development of production arising from the STR create the conditions for achieving an abundance of goods and services. At the same time, the fundamental revolutionary changes in the nature of the productive forces provide the material basis for eliminating the existing social distinctions.

Since the triumph of the socialist relations of production, the solution of subsequent social problems in communist construction has been most importantly connected with changes in man's position, with the elimination of the social distinctions between men in terms of their work and status in the process of actual production. This also applies to such important problems as the conversion of agricultural labour into a sort of industrial labour, the elimination of the everyday and cultural distinctions between town and country, and the organic fusion of manual and mental work in men's production activity.

The solution of all these tasks implies a social orientation in advancing scientific and technical progress, and this naturally also implies definite changes in men's cultural standards, and so on.

The STR, working revolutionary changes in science and technology, gradually moving into production and remodelling the very structure of the productive forces and the organisation of social production, at the same time works a radical change in the content of men's work and the nature and level of their skills, so helping to shape the harmoniously developed man and work adequate to his requirements.

The advantages of socialism in using the STR's potentialities are also connected with the economic integration of the

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[1] *Man—Science—Technology*, Moscow, Politizdat Publishers, 1973, p. 235 (in Russian).

socialist-community countries, which provides extensive potentialities for improving the specialisation and cooperation of production and all-round exchanges of scientific and technical experience among the socialist countries.

A number of intergovernmental organisations have already been set up by the socialist countries, and these help to accelerate scientific and technical progress and make it more effective.

Among these organisations is the Central Controller's Office for the Integrated Energy Grids of Bulgaria, Hungary, the GDR, Poland, Romania, the USSR and Czechoslovakia. The socialist countries have carried out joint R & D projects in atomic energy, notably, the design of new types of reactors and other plant; and work is in progress to draw up joint plans for developing production facilities for atomic engineering.

In 1964, they set up their Organisation for Cooperation in the Roller Bearings Industry, Intermetall, an organisation for cooperation in ferrous metallurgy, and Agromash, which coordinates the development and manufacture of farming machinery for fruit, vegetable and vine-growing. In 1972, they set up Interatominstrument, an international economic association, Interetalonpribor, a research and production association; in 1973, Interatomenergo, and in 1974, Interchimvolokno. In 1972, they set up Intersputnik, an international organisation for space communications whose purpose is to extend cooperation and coordinate efforts in the design, development and operation of space communications systems.

The first joint space flight by a Soviet and a Czechoslovak cosmonaut (Vladimir Remek) was held in 1978, and this was followed by joint flights staged by the USSR and the GDR, and the USSR and Poland and so on. Preparations are in progress for joint flights with other socialist countries.

The International Centre for Scientific and Technical Information, set up in 1970, has a great part to play in accelerating STR processes.

Integration has been gaining in depth. Addressing the 24th Session of CMEA, the Chairman of the USSR Council

of Ministers pointed out the need further to intensify the division of labour, and specialisation and cooperation of production, especially in engineering.

The decisions of the 25th Congress of the CPSU set the task of ensuring ever closer coordination and pooling the efforts of the USSR and other CMEA countries in tackling the tasks of scientific and technical progress.

In contrast to socialism, capitalism has definite limitations in using STR achievements, and these stem from the self-seeking interests of the exploiter classes.

The limitations which present-day capitalism imposes on the STR and the way it distorts its socio-economic consequences are described in the Main Document adopted by the International Meeting of Communist and Workers' Parties in June 1969. It says: "...capitalism is using the scientific and technological revolution to increase its profits and intensify the exploitation of the working people.

"The scientific and technological revolution accelerates the socialisation of the economy; under monopoly domination this leads to the reproduction of social antagonisms on a growing scale and in a sharper form. Not only have the longstanding contradictions of capitalism been aggravated, but new ones have arisen as well. This applies, in particular, to the contradiction between the unlimited possibilities opened up by the scientific and technological revolution and the roadblocks raised by capitalism to their utilisation for the benefit of society as a whole. Capitalism squanders national wealth, allocating for war purposes a great proportion of scientific discoveries and immense material resources. This is the contradiction between the social character of present-day production and the state-monopoly nature of its regulation. This is not only the growth of the contradiction between capital and labour, but also the deepening of the antagonism between the interests of the overwhelming majority of the nation and those of the financial oligarchy."[1]

The apologists of capitalism claim that the STR tends to change the nature of capitalism and just about automatically solves all of its social problems.

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[1] *International Meeting of Communist and Workers' Parties, Moscow 1969*, p. 19.

Theorists in the United States and Western Europe who have undertaken this thankless task try to paper up the contradictions and cracks in the façade of present-day capitalism by presenting scientific and technical progress as the progress of capitalism, which they have designated as the "new industrial society" and the "post-industrial society".

They insist that it is not property relations and the class structure of a society that are its chief characteristics but the technological level and that of scientific organisation of production and this subterfuge allegedly shows, that progress in technology and organisation of production is identical with society's social progress.

They refer to some purely superficial changes in what could be called the façade of the social formation. There is the depersonalised management of the big corporations; the emergence of a stratum of executives who are not owners but who efficiently do the will of big business; and profit-sharing, all of which are depicted as the withering away of capitalism and its gradual transformation into a developed "industrial society". In this way, the various purely technical phenomena and organisational and managerial measures used by capital are artificially separated from their social-class basis and are presented as premises for some new "industrial society" without classes and class contradictions.

"Any industrial society as such," writes Raymond Aron, "has the purpose of controlling nature and men, and the inevitable consequence of this is men's domination of men, together with it also a multiplication of wealth and goods."[1]

The suggestion here is that the "multiplication of wealth and goods" should compensate for "men's domination of men", a highly typical scale of values.

According to the same recipe, STR processes are used to justify the theory of the "post-industrial society" which is to be a substitute for the Marxist theory of the succession of social formations and transition from capitalism to socialism. The inventors of this theory assert that the capitalists cease to be the protagonists in the capitalist system and give way to a scientific and technical élite which help to

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[1] R. Aron, *Trois essais sur l'âge industriele*, Paris, 1966, p. 85.

transform the political system, with theoretical knowledge playing the central role.

Among those who seek to cover up the class content of all the processes in the development of the capitalist economy is Zbigniew Brzezinski, who declares: "Knowledge becomes a tool of power, and the effective mobilisation of talent an important way for acquiring power."[1] Referring to "the technotronic civilisation" he says that the main task will be to find the effective methods to use resourceful people rationally.

In this way, the advocates of the capitalist system now seek to embellish its façade, camouflage private property, class contradictions and capitalist relations of production. They make no secret of their effort to ignore and bypass the problem of property and class struggle. Peter Drucker, the US management expert, claims that the class struggle has been done away with, first, with the help of new technology, which created a new, more productive and better paid labour and second, with the help of education, which opened the possibility for the ever growing number of the poor background children to tear themselves away from the class, to which they were fastened by the Marxist ideology.

Drucker uses the past tense to show that all of this has actually occurred, but official statistics in various countries, notably, the United States, blast these optimistic claims.

> The *Statistical Abstract of the United States* published by the Bureau of the Census contains the following data.[2]
>
> In 1974, 22.8 per cent of persons of 25 years and over had only gone through primary school. For the same group of black people, the figure was 36.6 per cent.
>
> Discrimination against non-whites continues to be commonplace. According to the same source, in 1974, 3.5 per cent of whites had less than 5 years of schooling; while the figure among Chicanos was 26.5 per cent, and Puerto-Ricans, 17.6 per cent.

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[1] Z. Brzezinski, "America in the Technetronic Age. New Questions of Our Time", *Encounter*, January 1968, Vol. XXX, No. 1, p. 18.

[2] See *Statistical Abstract of the United States, 1975*.

According to 1970 data, among the population of 14 years of age and over there were nearly 1.5 million illiterates, of whom 0.7 per cent were whites, and 3.6 per cent blacks.

All these facts testify to a naked urge to perpetuate the present state of things: the existence of rich people possessing all the material and cultural benefits, and the rest who create all these benefits but use only a small part of them. Aron shows this very clearly when he says: "...society is not and cannot be ruled by scientists." Further on he puts it more bluntly: "...some groups will continue to feel shut off from higher culture by the very nature of the work they do... On this hypothesis, it has seemed probable that the demand for equality would be individual rather than collective."[1]

This is a frank call for perpetuating a high-culture élite on the one hand, and the bulk of the population, "second class citizens", on the other, who will even be unable to unite in their urge for equality.

Actually, the class nature of the capitalist society is not changed in any way despite the fact that capitalism makes use of the STR to boost the productive forces and certainly creates the material prerequisites for building socialism (after a socialist revolution) and despite the fact that capitalist governments increasingly intervene in the development of science and technology and use scientists on a national scale.

The collection of articles by a group of Soviet and Czechoslovak scientists says that the sharp rise in science and technology has not and could not in itself ensure the elimination of injustice in the distribution of the social wealth. The theory of "equal opportunities" cannot conceal the fact that class contradictions and the consequent social inequality continue to be the hallmarks of the capitalist society".[2]

An analysis of the facts shows that *the STR may provide the basis for a radical solution of social problems and elimination of social distinctions between men only when the cardinal social problem—the problem of property, which constitutes*

[1] R. Aron, *Progress and Disillusion*, Frederick A. Praeger Publishers, N. Y., 1968, pp. 41-42, 43, 44.

[2] See *Man—Science—Technology*, p. 171.

the basis of the relations of production—is solved, and solved in favour of socialism.

Let us note that the STR also tends to intrude into this sphere within the framework of capitalism. It stimulates a much higher degree of socialisation of production, because the major scientific and technical projects frequently have a larger framework than the biggest corporations, which is why they have to be carried out on a national or even international level. But this does not at all signify the elimination of private property in the means of production or, consequently, do away with the chief contradiction of capitalism.

Under capitalism, scientific and technical progress is contradictory. In the developed countries (and this is especially evident in the United States) the capitalist state finances the development of basic and applied research on a considerable scale, and provides these with the material base. As a result of the operation of the law of value, the mechanism of profit and competition (and in the cases directly or indirectly connected with arms manufacture, government appropriations as well) induces the necessary changes in the sectoral structure of production.

The radical changes in the nature of labour brought about by scientific and technical progress run into deep contradiction with the nature of capitalism, and sharpen and expose the antagonism between the interests of the working class and the other working people, on the one hand, and the ruling élite which has the means of production and which appropriates the surplus-value created by wage-labour, on the other.

Here are some statistical data to bear out this conclusion.

In the 24 years from 1954 to 1977, US industrial output increased 2.5-fold, and the number of workers employed in manufacturing and extracting dropped from 14,921,000 to 14,795,00, i.e., by 0.8 per cent. In the USSR, from 1950 to 1977, industrial output increased 10.9-fold, and the number of workers from 12.2 million to 28.5 million, or 134 per cent. It is essential to note here that labour productivity in USSR industry in that period increased by 370 per cent, and in US industry by 157 per cent. Meanwhile, the USSR does not just have no unemployment, but has in fact a large labour shortage, while the United States has a stable and growing army of unemployed. This means

that even with the much lower rate of labour productivity growth (3.4 per cent a year in the United States as compared with 6 per cent in the USSR), capitalist relations of production cannot ensure a growth of employment in industry.

In the 1950s, the number of officially unemployed fluctuated between 1.8 million and 4.6 million, in the 1960s, from 2.8 million to 4.7 million, and from 1971 to 1977, from 4.3 million to 7.8 million; besides, from 1975 to 1977, it did not drop below 6.2 million, and reached 8.6 million.

These data demonstrate the fundamental distinctions between the social consequences of scientific and technical progress under capitalism and under socialism. The growth of labour productivity under capitalism induced by technical progress and intensification of labour runs into contradiction with the limited rates of growth in production. And this naturally has an effect on the employment dynamic.

> Thus, only in 8 industries in the USA (mining, food, textiles, timber and woodworking, oil refining, leather and footwear, metallurgy and transport engineering) the number of employed workers in the 24 years from 1954 to 1977 dropped by over 1.2 million. These were miners from the Appalachians, textile workers from New England, steel workers from Pennsylvania and Ohio, engineering workers from Detroit, and so on, among them the inhabitants of so-called ghost towns which even official US agencies designate as "hardship areas".

Let us note that even the fastest growing industries connected with the realisation of STR achievements cannot make use of those made redundant in other industries. Indeed, there is an excess of labour-power in some of the new industries as well.[5]

> Take the aerospace industry. With a 26 per cent growth of output from 1953 to 1975, the number of persons employed in the industry dropped from 586,000 to 243,000, i.e., by 343,000 persons, or 59 per cent. Incidentally, this largely refutes the "compensation" theory which many US economists present in an effort to show that the high technology industries allegedly take up the labour slack resulting in other industries.

We find a very similar situation in agriculture.

From 1950 to 1974, farm produce in the USSR increased by 144 per cent, and labour productivity by 275 per cent, with the result that the number of persons employed in agriculture dropped by 15.4 per cent, but this contingent was fully absorbed by the rapidly growing non-agricultural industries.

In US agriculture things were different. As a result of intensive technical re-equipment, labour productivity in this sector in the same period increased by roughly 270 per cent, while output went up by only 53 per cent, while employment in US agriculture dropped by 5.78 million persons.

US economists seek in every way to minimise the effect of the processes in which those employed in the sphere of material production are being made redundant by technical progress. They refer to the marked growth of employment in the nonproduction sphere. Employment in this sphere, including trade, (from 1950 to 1975) actually went up from 22.7 million to 52.2 million, that is, by 29.5 million persons, or 130.5 per cent, but this growth was much lower than the increase in the population of working age in the same period (51.9 million persons). As a result, the number of officially registered unemployed (which falls far short of the whole contingent) came to 5 million in 1971, to 8.2 million in early 1975, and to an average of 7.0 million in 1977.

All these processes naturally sharpen the social contradictions in the country, one of whose manifestations is the growth of the strike struggle.

According to the US Department of Labour, the number of man-days lost through industrial actions in the ten years from 1968 to 1977 came to 412 million, as compared with 277 million for the preceding 10 years between 1958 and 1967, i.e., an increase of 50 per cent.

Let us also bear in mind that according to the evidence of Hiroshima and Nagasaki and the war in Vietnam, *present-day capitalism has repeatedly demonstrated the use of the vast potentialities of the STR mostly for destructive purposes.*

One characteristic fact in this context is that the Federal Budget outlays on R & D for military purposes came to 8.7 billion dollars in 1974, or nearly 40 per cent more

than the Johnson Administration spent in five years on its so-called war on poverty. This kind of use of scientific and technical progress naturally leads to cutbacks in public welfare programme.

Those are some of the facts which incontrovertibly prove that under capitalism today the STR results not only in a growth and development of the productive forces, but also in a sharpening of the class struggle.

Consequently, although historically the STR is also proceeding in the developed capitalist countries, it is by its very nature and potentialities adequate only to socialism. It alone is capable of realising fully and for the benefit of mankind all the potentialities of the STR. In complete accord with the Marxist theory of the development of the productive forces and the relations of production, the theory of the succession of social formations, the current STR quite naturally characterises the new stage in the development of the material productive forces which fully meet the requirements of the developed socialist society today, and is capable of ensuring the buildup of the material and technical basis of communism over the long term.

CHAPTER TWO

THE MAIN TRENDS IN DEVELOPMENT OF MATERIAL PRODUCTION AND THE SHAPING OF THE STR

1. PECULIARITIES OF DEVELOPMENT OF MACHINE PRODUCTION

The current STR forms new stages in the development of large-scale machine production. In order to comprehend the content and the basic trends in its formation and further development, there is a need to examine the main stages and logic of development of large-scale machine production, beginning with the stage of its origination, which Marx described in Chapter XV of Volume One of his *Capital*, up to the modern and foreseeable stages reflecting the maturity and development of the STR.

In Chapter XV, especially in its first paragraph entitled "The Development of Machinery", Marx gives a profound analysis of the basic trends in the development of the productive forces. Summing up a vast array of facts, he analyses the contemporary and visible prospects and stages in the development of large-scale machine production, and brings out the contradictions which stimulate this development. At the same time, Marx shows how the development of machines influences the social division of labour and the complexification and expansion of the sectoral structure of industry, how it influences the nature of the process of labour itself, how it alters the functions of the worker in the process of labour and how it influences the condition of the working class and the whole process of reproduction.

"Modern industry," Marx wrote, "never looks upon and treats the existing form of a process as final. The technical basis of that industry is therefore revolutionary, while all earlier modes of production were essentially conservative. By means of machinery, chemical processes and other meth-

ods, it is *continually causing changes not only in the technical basis of production, but also in the functions of the labourer, and in the social combinations of the labour-process.* At the same time, it thereby also *revolutionises the division of labour within the society*, and incessantly launches masses of capital and of workpeople from one branch of production to another".[1] [My emphasis—*S.H.*].

If such is the influence (and it is such) that the advance of machine production exerts on the whole process of reproduction, can political economy afford to ignore the stages and logic in the development of the productive forces and the stages in the development of large-scale machine production? Of course, it cannot.

This is all the more important because within the limits of each mode of production (notably, within the framework of capitalism and of the communist social formation) the development and stages of machine production have a substantial influence on the development of the relations of production, i.e., on the generally recognised subject-matter of political economy.

It is quite obvious that the transition from premonopoly capitalism to monopoly imperialism is closely connected with the stage in the development of machine production which took shape in the early 20th century. It is apparently possible and necessary also to establish the functional ties between the contemporary stage in the development of machine production, which has taken shape since the Second World War, and the new phenomena which characterise capitalism and the development of the capitalist countries today.

An analysis of the stages in the development of large-scale machine production which have taken shape and will take shape in the foreseeable future is necessary from the practical standpoint, in elaborating the problems of the political economy of socialism. It is especially necessary today, in this period of the building of the material and technical basis of communism in the USSR. Under the planned socialist economy there is an insistent need to comprehend and to anticipate the basic trends in the development of production, its technical and technological aspects, and their impact on the structure of production, the nature

[1] Karl Marx, *Capital*, Vol. I, p. 457.

of labour and the specialisation of workpeople. Thus, the solution of such basic social problems of communist construction as the elimination of the still existing substantial distinctions between town and country, between mental and manual work, the elimination of social distinctions between men in the process of production, and the conversion of work into a prime necessity of life, is directly connected with the new advancing stages in the development of large-scale machine production.

The building of the material and technical basis of communism is a conscious and balanced process effected by the socialist society through the purposeful use of the objective laws governing the development of the productive forces.

The material and technical basis of communism is, in fact, already being built up. The technical policy and investments effected, say, in the second half of the 1970s will determine the technical level and sectoral structure of production in the 1980s and partially in the 1990s; those who are now being educated and trained will constitute the cadres who will have to work in industry and other sectors in the 1980s and the period beyond.

A schoolboy who, say, in 1979 was attending the eighth grade of secondary school, will be only 36 years old in the year 2000, a second-year college student will be 39 years old, and a first-year post-graduate will be 44 years old. These are the basic cadres of the early 21st century. They will have to face the production, technology and science of the beginning of the third millennium of our era, and it is our duty to help them avoid the "future shock".[1] They will be the subjects of further progress and advance in the development of science, technology and production, and it is our duty to help them cope with the vastly complicated and responsible tasks.

The curricula in secondary, secondary special and higher schools must evidently even now take these tasks into account and start from the foreseeable peculiarities of material production, and the conditions and nature of labour as these will take shape by the end of the 20th century. When it comes to training men with a broad general polytechnical grounding, it is necessary that in the teaching of sciences

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[1] See Alvin Toffler, *The Future Shock. The Eco-Spasm Report.*

like physics, chemistry, biology and mathematics, they should be acquainted with the basic technical and technological lines in highly developed production, and also with the basics of cybernetics. This should help them to solve the main problem, which is effective assimilation and further improvement in the technological basis of production.

All of this requires thorough analysis of the basic trends in the development of production, of its technological aspects and structure. The basic assumption should be that the main elements of the material and technical basis of communism are already being shaped today, which is why any decisions on technical policy, the structure of production, specialisation of personnel, etc., should rest on well-grounded prognostication with an eye to the main lines of the current STR.

2. THE MAIN PHASES IN THE DEVELOPMENT OF LARGE-SCALE MACHINE PRODUCTION

A number of phases in the development of large-scale machine production have run within the framework of capitalism. Socialism finds machine production at the historical stage which has taken shape by the time of the socialist revolution in each country. It is then developed as the material and technical basis of socialism and then of communism are built up. In the USSR, the buildup of the material and technical basis of communism started from the level large-scale machine production had reached between the 1960s and 1970s.

The period of building up the material and technical basis of communism in the USSR coincides in time with the STR, and this will naturally entail the shaping of a new phase in the development of large-scale machine production.

The development of large-scale machine production runs in two directions: vertically, as it and each of its functional elements—machinery, production methods, objects of labour and organisation of production—are improved and raised to ever higher stages of their development; and horizontally, as large-scale machine production is introduced into an ever broader range of sectors of material (and subsequently also of non-material) production, the sphere of the services,

and the dissemination of knowledge and spiritual values.

This means that every phase in the development of large-scale machine production is in accordance with definite trends in the changing structure of the whole of material production, and the structure of the individual industries, in the light of the potentialities of scientific and technical progress, and the conditions and specifics of the given country.

It is also evident that at every phase of its development, the state of large-scale machine production and of the relations of production dominant in society determine the status of the worker, his functions as a participant in production, and accordingly the practical experience, skills and educational level which he must have.

Because each given phase in the development of machine production in a concrete country has to run within the framework of a definite social formation, its socio-economic characteristics depend on the relations of production, above all property relations, which are dominant in the society and which determine the main purposes of production, the relations among men in the process of production, the lines and nature of the use of the results of the surplus-labour of those who work and their status in production and society.

Here I intend to analyse *the logic underlying the development of machine production itself and its component material elements, and also the logic behind the changes in its sectoral structure, which is required to determine the main lines of further change in the basic elements of production in connection with the advance of the STR.* I intend to examine the social consequences of these changes in subsequent chapters.

If one were to try to comprehend the past development of large-scale machine production and its foreseeable prospects, one could (approximately, of course) map out the following phases in the development of large-scale machine production.[1]

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[1] Describing the phases in the development of large-scale machine production, I intend to characterise the system of machines, degree of labour mechanisation, differentiation and cooperation of labour at each phase and the contradictions which arise in the development of large-scale machine production and which help to advance it.

The first two phases relate to the past, the third partially to the contemporary large-scale machine production, and the fourth is now taking shape, and in its developed form, like those which will come after it, will evidently be fully developed only under communism.

It goes without saying that the successive phases in the development of machine production are not separated by any "partitions", for the elements of every future phase mature within the entrails of the preceding one. That is why the content and the time coordinates of each are fairly approximate and contain, especially when it comes to the juncture of two successive phases, some features which are typical of the preceding and of the subsequent phase.

Let us consider the main features characterising these phases.

Phase One. The instrument of labour provided the starting point for the industrial revolution of the 18th century, the transition from the handicraft tool to the three-element system of machines (consisting, as Marx said, of the motor mechanism, the transmitting mechanism and the tool or working machine). In these conditions, the number of tools that a machine can bring into play "is from the very first emancipated from the organic limits that hedge in the tools of a handicraftsman".[1] Marx adds: "The machine, which is the starting-point of the industrial revolution, supersedes the workman, who handles a single tool, by a mechanism operating with a number of similar tools, and set in motion by a single motive power, whatever the form of that power may be."[2]

Changes in the working machine made for changes in the other elements of the machine system. The increase in the size of various tools and instruments simultaneously set in motion by the machine ran into contradiction with the motor mechanism and required a sharp increase in its power rating and, accordingly, a new and more powerful source of motive power. The first such motor mechanism was the steam engine invented by James Watt.

This helped to shape the *complex of large-scale machine production based mainly on the motive power of steam. It is that phase of large-scale machine production that was charac-*

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[1] Karl Marx, *Capital*, Vol. I, p. 354.
[2] *Ibid.*, p. 355.

teristic of the beginning of the second half of the 19th century (i.e., the period in which Marx wrote Volume I of his *Capital*) *and which existed, in its essential features, up to the 1880s and 1890s.*

Such machine production used mainly natural objects of labour—natural raw and other materials, coming from the mining industry and agriculture.

The development of machine production, as it was noted even in that time, shapes the sectoral structure and raises the level of specialisation of production and, consequently, influences the social division of labour. "In proportion as machinery, with the aid of a relatively small number of workpeople, increases the mass of raw materials, intermediate products, instruments of labour, etc., the working-up of these raw materials and intermediate products becomes split up into numberless branches; social production increases in diversity. The factory system carries the social division of labour immeasurably further than does manufacture, for it increases the productiveness of the industries it seizes upon, in a far higher degree.... Entirely new branches of production, creating new fields of labour, are also formed, as the direct result either of machinery or of the general industrial changes brought about by it."[1]

The development of the productive forces connected with the progress of machine production tends to complexify the structure of the whole economy, giving rise to many new industries and lines of production, developing transport, communications, and so on.

When characterising the sectoral structure, one should note that *in the first phase the products of the extractive industries within industry as a whole tended to grow at a faster rate.* Their share in the whole of industry was relatively large, especially in the number of persons employed, because the fundamental technical reconstruction of the extractive industries, i.e., the introduction of machine production into these, took place in much later phases in the development of large-scale machine production.

Among the manufacturing industries, metallurgy, including foundry production and the making of metal articles, stood out in the metal industry, and in engineering, the making of locomotives and railway cars for the rapidly

[1] Karl Marx, *Capital*, Vol. I, p. 419.

developing railways. The machine manufacture of mechanisms (technological equipment) began to develop, but it was still relatively unimportant. The share of the chemical industry was extremely insignificant.

The food and the light industry had a leading place in terms of the number of persons employed and the value of the product. Wood-sawing was prevalent in the group of industries connected with wood-working, while the pulp and paper industry was just beginning to develop.

At that phase, technology, as a rule, directly corresponded to the product of labour produced in the given industry. *Differentiation and specialisation* of technological processes were still relatively low. Accordingly, industry turned out a relatively limited range of articles. This simplicity of technical and technological solutions also made for a certain simplicity in the choice of forms of organisation and management of production.

Although even in that period, the output of some manufactured articles like ferrous metals, fabrics and garments, and some foodstuffs was fairly large, there was no broad use of the methods for organising mass production on the principle of interchangeability of parts and units. Accordingly, the practice of technical measurement, like the manufacture of measuring tools and instruments was still in an embryonic stage.

The mechanisation of labour processes boiled down mainly to the use of mechanical motors to set in motion the main working machines, and with the design and development of the latter, to a gradual mechanisation of some shaping processes.

In these conditions, the differentiation of workers by trades and skills was almost entirely determined by the differences between the industries in which they worked. *Differentiation of workers by trades within industries was limited only by the very basic character of production* (weaving, spinning, finishing in the textile industry; blast, steel and rolling production in metallurgy; forging, foundry and mechanical working stages in engineering, etc.).

The functional specialisation of working machines which was just beginning in this phase naturally tended to limit the range of trades among workers servicing these machines; the functions of auxiliary workers, apart from unskilled auxiliary workers (feeders, as Marx called them,

for they merely feed the material of labour into the machine) were still to separate, and their number and share was relatively insignificant.

At the same time, even in that phase the rise in labour productivity in the sphere of material production had an influence on the general structure of employment, which "allows of the unproductive employment of a larger and larger part of the working-class, and the consequent reproduction, on a constantly extending scale, of the ancient domestic slaves under the name of a servant class, including men-servants, women-servants, lackeys, etc."[1]

In that period, *the natural sciences were still little connected directly with technology, let alone industrial production.* But even then, Marx noted the trend in machine production sharply to increase the application of science. "The principle, carried out in the factory system, of analysing the process of production into its constituent phases, and of solving the problems thus proposed by the application of mechanics, of chemistry, and of the whole range of the natural sciences, becomes the determining principle everywhere."[2] But science, according to John D. Bernal of Britain, was then still in a small laboratory of the professor or the backroom of the inventor. It is true that that period saw the laying of the scientific foundations for the comprehension of the structure of substance, with the creation of Mendeleyev's periodic system of elements, and Butlerov's formulation of the molecular theory of the structure of organic substances, which laid the foundations for organic synthesis in the future. In physics, the initially isolated forces—light, electricity, magnetism and heat—were joined together in a coherent electromagnetic theory. In mathematics, work was in progress to develop the basic mathematical formalism, whose most profound and fundamental sections in that period were virtually in no way connected either with technology or material production.

Although in that period, the technology of machine production was already largely based on the corresponding level in the development of the technical sciences, at that stage in the development of material production *the results of basic research in the natural sciences*—physics,

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[1] Karl Marx, *Capital*, Vol. I, p. 420.
[2] *Ibid.*, p. 434.

chemistry and biology—*were most conducive to an explanation of the world and not to a change of it, and had little influence on machine production.* The marked isolation of mathematics from the natural sciences made it impossible to obtain a quantitative characterisation of the qualitative explanations of natural phenomena which science produced. But as the subsequent record of scientific development has shown, natural phenomena can be governed, substances and reactions artificially reproduced, and new substances created only on the basis of quantitatively measured uniformities.

The second phase in the development of machine production *ran from the late 19th century until the start of the Second World War.* Like the first, it was marked by important changes, above all in the instruments of labour. But here there were also substantial peculiarities springing from the changes in the sectoral structure of production.

In the second phase, especially in the early decades of the 20th century, a *group of industries characterised by continuous processes* (electric energy, metallurgy, chemistry, oil refining, pulp-and-paper, cement, etc.) took shape within industry and subsequently *grew at the fastest pace.*

The instruments of labour in these industries differed markedly from the three-element machine complex described above. I shall deal with them in greater detail when analysing the third phase.

Important and *radical changes took place in the second phase also within the system of machines in manufacturing industry with continuous processes, as characterised by Marx.*

As each of the elements of the three-element machine system developed, the role and conditions of their interaction changed, giving rise to dynamic contradictions, which provided the motive force for the further advance of all elements of machine production.

Improvement of technology and the progressing specialisation of operations steadily engendered more and more new types of working machines and working instruments. The development and complexification of transmitting devices, the rapid growth of the manufacture of transport facilities, and the extensive use of rack wheels called for the massive output of various types of gears. The result was the appearance, alongside lathes, drilling machines and planers, of families of milling, gear-cutting and gear-grinding machines.

The growing demand for frame parts, like casings and housings, in which various types of motors and transmitting devices were installed, and the development of ever more powerful energy units led to the growing output of boring and broaching machines and vertical lathes. The increasing demand for precision working led to the development of more and more new types of grinding machines. A whole range of working machines was developed to work metal by means of pressure and plastic deformation, like diverse presses, hammers, etc. Special foundry, welding, thermal and other machines appeared on the scene.

The result was an *intensive process of functional specialisation of working machines*, each of which ever more productively performed a limited range of operations necessary for making various parts and articles. Similar processes occurred in other industries.

The radical changes and complexification of the products of labour turned out on the basis of large-scale machine production and, in particular, the transition to large-scale machine production in the making of machines themselves sharply increased the number of parts constituting the manufactured products.

The growing scale and complexification of production dictated the need for a radical restructuring of its organisation, a transition to mass production of various kinds of mechanisms and other compound articles. While intensifying the division and specialisation of labour processes, such trends sharply increased the scale and share of assembly operations. Manual performance of all the operations involved in assembly turned out to be incompatible with the scale of mass production, and this made for the emergence of an exceptionally broad range of working tools performing diverse assembly and attendant operations, which at first were entirely manual. But as the labour-intensiveness of assembly work increased, there was an ever greater need to mechanise these operations and, accordingly, to develop mechanised handtools. Such tools, most of which are very small in size, required the most diverse transformation of motive power, which was frequently very small itself.

Thus, together with the trend towards a considerable increase in the size of working machines and tools there was a growing tendency to make many tools and working

machines more compact. The growing demands of precision and interchangeability of machine parts stimulated the emergence of a broad range of precision tools and, together with them, of a numerous family of control and measuring tools and instruments ensuring the necessary precision and interchangeability of parts and units.

These changes in working machines and, in particular, in working instruments naturally ran into contradiction with the old sources of motive power—the steam engine—and the cumbersome transmitting mechanisms. There arose an insistent need for power that, while coming in much greater volume, could at the same time be used in larger or in any desirable small quantities, however the equipment was located in space. *There arose the need for radical changes in the transmitting devices as well.*

The intricate and extremely cumbersome system of drives from the central or group steam engine to the working machine made for some rigidity in the existing arrangement of equipment. This produced an acute need in a drive from the engine to the working machine and working tool that would be multi-purposeful, flexible and wieldy.

The further development of large-scale machine production called for an individual drive that could be developed only through a transition to a new motive power, through a substitution of electricity for steam.

Electricity did provide the new motive power which accorded to the growing and ever more complex large-scale machine production.

The emergence and rapid development of the centralised generation of electric power, together with the development of the techniques for transmitting electric current over ever longer distances, brought out the motor mechanism from the three-element machine system of which Marx wrote. The generation of electric power became an independent industry. Current-carrying communications, individual electric drives, and built-in working electric motors, replaced the old motor mechanism and made working machines (and wherever necessary, even each working tool), their power, size and speed, their location and arrangement in space, and the regime of their operation independent of the power, the location, and operation of the central or group motor.

The spread of the individual electric drive, for its part,

worked a radical change in the nature and functions of the transmitting mechanism, and it was altogether eliminated as a part of the machine complex separate from the working machine.

Of course, the system of transmitting energy from the central motor (i.e., from the electric power station or substation) to the electric motor of the given machine-tool remained, but these functions were now performed by ordinary current-carrying communications. At the same time, the need also remained for the drive from the motor, built into the operating part of the machine-tool (be it the spindle on which the working part rotated, or the tool holder and the rest in which the working tool was fixed). But the functions of this transmitting device now no longer (and not so much) consisted in transmitting the energy itself (for with electric drive such transmission is altogether elementary), as in regulating the type and direction of movement, the speed, etc., of the operating part of the machine.

Accordingly, the new transmitting device, which had earlier been no more than a connecting link transmitting power from the motor to the working mechanism also became a connecting link between the operator and the operating part of that machine (and this gradually became its main and overriding function).

With the growing range of tools in technological equipment and the sharp increase not only in the number of simultaneously operating tools, but also in their size and other parameters, this new transmitting device reduced man's dependence on his limited physical capabilities in governing very large or very small, or simultaneously very many tools or other executive mechanisms. In this transmitting device there appeared and began to develop the embryo of the future controlling device of the epoch of automation.

Thus, *three component elements of the machine complex located side by side—the motor mechanism, the cumbersome transmitting mechanism and the working machine—were fused into a single mechanism in which the motor and the transmitting device were organically built into the working machine.*

The energy autonomy of working machines arising from the use of the built-in electric drive also helped effectively to develop the all-round specialisation of working machines and working tools.

This phase is also characterised by important changes in the technological processes used in the key industries. The development of diverse new functionally specialised types of labour instruments did away with the old simplicity of techniques. The improvement of working machines led to a marked intensification of technological processes and the introduction of more progressive and economical methods of shaping. This was facilitated by the development of mass production of interchangeable parts and units which required technological backup for the precision of blanks, parts and articles. Advances in the industrial use of electric power and chemical processes led to the emergence and development of electrical and chemical technological processes, which, in particular, provide for the necessary precision of parts and units, all kinds of hardened coatings, etc.

The built-in electric drive and the potentialities which go hand in hand with it (and which it simultaneously provides) for further developing and specialising working machines paved the way for the *emergence and progressive spread of a higher form of organisation of machine production: the assembly line in industrial production.*

This process went forward as follows. Earlier on, the central or group motor and mechanical transmitting devices made it inevitable that the working machines grouped round it would be largely homogeneous. Each motor had a more or less limited range of transmitted movements, speeds, etc. This predetermined the technological arrangement of production sections where mainly homogeneous working machines were grouped (turning shops, drilling shops, thermal shops, etc.).

Meanwhile, changes were taking place in the structure of the products (especially those turned out by engineering enterprises), in the techniques of their manufacture and in the development of the working machines themselves, and these led to a situation in which the efficiency of production was constrained by the technological pattern of shops at the enterprises. Structures of the articles were increasingly compound, and the process of manufacturing each unit and part increasingly consisted of more and more operations. At the same time, two trends, which also stimulated changes in the structure and organisation of production, emerged in the development of working machines in the process of their progressive specialisation.

On the one hand, there was the above-mentioned functional specialisation. Alongside this trend, with the development of mass production, there emerged another trend in the specialisation of working machines: item specialisation. This developed in industries like automobile and tractor making. Specialised machine-tools were developed for the multi-positional working of cylinder blocks and cylinder heads for automobile and tractor engines, multi-positional machine-tools for working the numerous crank-cases which are component parts of the automobile, and so on.

These trends in the development of product structure, changes in the technology and the specialisation of working machines ran into contradiction with the prevailing technological pattern of production shops and, accordingly, with the technological arrangement of equipment (according to the principle of functional homogeneity). After each operation, numerous parts had to be transported to the next functional shop, and this markedly increased the labour-intensiveness of the transfer processes, complicated accounting and control of production.

In this period, the individual electric drive eliminated the imperative need to group homogeneous machine-tools together.

This produced the need and offered the opportunity to develop the structure of sections and to place equipment according to items, and on that basis to use the assembly-line organisation of production, which is being ever more extensively used in modern industry and which continues to be organisationally important even under automation.

In the second phase of machine production, *corresponding changes also occurred in the sectoral structure of industrial production.*

The generation and industrial use of electric power rapidly developed, the production of ferrous metals and engineering, whose intrasectoral structure was increasingly diversified, developed at faster rates, and the electro-technical industry was ramified. With the growth of motor (and especially automobile) transport, oil refining gained in depth and grew rapidly. The chemical industry, whose inner structure was likewise complexified, developed markedly.

The intensive growth of the manufacturing industries, together with their rapid sectoral differentiation, led to

a situation in which *the rate of growth in the extractive industry* in that period *began markedly to lag behind that of manufacturing*.

In that phase, the mechanisation of production ranged mainly over the basic technological processes in the working and shaping of metals, gradually doing away with the use of the worker's motive force in the fulfilment of the basic technological processes. Electricity and the built-in drive paved the way for the incipient mechanisation of ancillary processes in production.

In that phase, together with the functional specialisation of working machines there was extensive specialisation of workers by trade within the framework of each industry, with a separation of the functions and trades of workers servicing the equipment. With the introduction of multi-operation techniques, transfer processes tended to increase and become more complex, and that produced the need for special ancillary, notably transport, workers.

A most important social result of these trends was the growing concentration of production and, with it, the concentration of manpower at large enterprises. This raised the level of working-class organisation; trade unions organised on the trades principle increasingly gave way to trade unions organised on the production (sectoral) principle, thereby strengthening the proletariat's positions in the class struggle against the capitalists.

Consequently, *the second phase, with a further considerable rise in the productivity of labour, is characterised by a switch everywhere from steam to electricity, a growth of mechanisation in production and radical changes in the machine complex, which Marx analysed, the development of machine assemblies used in industries with continuous technological processes, and marked changes in the sectoral structure and trades makeup of the workers.*

Another important social result was that in that phase there was a growth of the most capital-intensive industries—metallurgy, chemistry, electric power. Because of technical progress, the most efficient enterprises were the big ones, while the ever more extensive use of chemical processing of primary materials intensified the combination of production. This created the material prerequisites and the technical necessity for concentrating production and, accordingly, for concentrating and centralising capital.

The growing productivity of labour brought about by the progress of large-scale machine production created in the industrially most advanced countries the material prerequisites for the export of capital, so that it is quite natural that at that phase in the development of large-scale machine production pre-monopoly capitalism developed into monopoly imperialism, which Lenin so thoroughly analysed.

Phase Three. In the early decades of the 20th century, new trends were in evidence in the development of all the elements of large-scale machine production, and these were sharply intensified by the Second World War, which made tremendous demands on material production, science and technology. As a result of the operation of these trends there gradually took shape the contemporary machine production which was characteristic of the 1950s and 1960s, and even more so of the 1970s.

How did the basic elements of large-scale machine production change in the third phase of its development?

Fundamental changes occurred in the development of working machines. These were largely connected with the major shifts in the sectoral structure of industrial production. Alongside the rapid development of chemical production proper, there was an ever faster growth of industries based on various versions of chemical (usually continuous) technology: the metallurgy of ferrous and nonferrous metals, oil refining, the rubber, pulp-and-paper, and cement industries, some food industries.

In these industries, the basic technological equipment consists of ever larger and more powerful closed container capacities, mostly with continuous operation, in which the chemical processes leading to the formation of the final product take place. The operation and efficiency of these assemblies are determined by a combination of numerous variables: the physico-chemical composition of the components loaded into them, the speeds and frequency of supply, temperatures, pressures, and so on.

The specifics of these working machines which make them distinct from the machine complex characterised by Marx consists above all in the fact that they do not effect shaping processes, which is why they have no working tool to act on the form of the object of labour. In these machines, substances are transformed, resulting either in the

separation of various types of raw and other materials or the synthesis of new substances with the use of various components of the raw materials (organic synthesis chemistry, biological chemistry, etc.). At the same time, in assemblies of this type the functions of the transmitting device are markedly complexified, for instead of transmitting energy to the executive mechanisms, it has to regulate the action of numerous variable factors which determine the work of the assembly.

The complexity of this set of variable factors gradually tends to exceed man's capacity as the governing agent and sharply raises the problem of optimising technological regimes and processes, and determining and achieving such optimisation by means of machines and eventually, by means of computers.

Substantial changes also take place in the traditional instruments of labour used in manufacturing industries with discrete technology and quantified products (above all in metal-working).

The intensive spread of mass assembly production, together with the further development of the individual (single and multi-motor) electric drive, have simultaneously enhanced both the functional improvement and the item specialisation of working machines.

At first, ever greater use is made of multi-positional machine-tools specialised in the working of a short range of parts and articles, and sometimes even of one concrete part or article. These machine-tools have an ever greater place in the rapidly growing assembly-lines of mass production and are an important condition for their high economic efficiency. These trends are vividly illustrated by the automobile industry with its multi-positional and strictly specialised machine-tools.

However, with the development of large-scale machine production and its assembly form of organisation, the use of these highly efficient machine-tools of item specialisation runs into contradiction with the fast pace of technical progress and converts it from an accelerating into a retarding factor.

The functionally specialised working machine is more flexible and adaptable to the possible changes in the objects of production than the item-specialised technological equipment. Strictly speaking, the functionally specialised working

machine, almost universal in the fulfilment of its functions, is indifferent to the object of production, because it effects a definite function of working: turns, mills, grinds, etc. Consequently, functionally specialised machine-tools react more flexibly to the change of objects of production. Meanwhile, technical progress is increasingly materialised in the ever more frequent change of objects of production—the products of labour—with the change of their structure and type and the appearance of totally new articles. Highly specialised item machine-tools designed to work an extremely narrow range of parts or articles take much effort to switch to the working of new items. At the same time, because of their complexity, they are expensive, and this prevents them from being removed with the change of the objects of production.

On the other hand, the item-assembly organisation of production, within the framework of which corresponding multi-positional machine-tools are most extensively used, is undoubtedly the highest and most progressive form of organisation, whose economic advantages are unquestionable. There is every reason to assert that item-assembly organisation, combined with automation of production, is the most rational form of organisation of modern industry. Consequently, a return from the assembly-line to the old functional shop structure, which reacts much more easily to the frequent change of objects of production would be to slow down technical progress, and that is impossible.

This *dialectical contradiction in modern technical progress is resolved through the synthesis of the functional and the item specialisation of working machines*: *the development of flexible technological equipment.* This synthesis is effected through the utmost improvement of functional units constituting the technological equipment, and their flexible arrangement in item machine-tool assemblies or lines.

The requirement of flexibility becomes an ever more important criterion of the progressiveness of the working machine and one of the chief criteria of the economic effectiveness of technical policy.

The working machine organically blending into a single whole the three elements of the machine complex (motor mechanism, transmitting mechanism and the working machine proper—the executive mechanism) is once again

being taken apart. But these parts are not the old elements of the machine complex, but a functionally specialised and perfected "micro-complex", a power pack which contains and blends together the motor, the transmitting device and the working mechanism.

Machine-tool assemblies—an item combination of such power packs—are no longer simply a single machine complex, but a real system of machines in which each element contains all the three parts of the machine complex characterised in *Capital.* At present, this is the highest form of the primary cell of the machine mode of production. It exerts a considerable influence both on the nature of the technical division of labour, and on the type and skill of the worker. It is also fraught with the elements which are to be fully developed in the subsequent phases of machine production.

Two other important trends need to be noted in the development of working machines in this period.

The first of these, which does not change the qualitative nature of working machines, although it is of great importance, (as I shall show later) *consists in the multiplication of the unit capacity and productivity of the basic types of power and technological equipment.* This trend continues today as the next, fourth phase in the development of large-scale machine production takes shape.

Hydraulic and steam turbines, whose capacity early in this century was rated in tens of thousands or even thousands of kilowatts, now have a per-unit capacity of 300,000 or even 800,000 kw. In the USSR, turbines with a capacity of 1.2 million kw and over are already being designed and engineered.

Blast furnaces, whose net volume even in the years before the Second World War came to 400-500-600 cubic metres, has recently reached 1,700-1,800 cub. m. The USSR has giant blast furnaces of 2,700-3,000 cub. m. and even one of 5,000 cub. m.

The basic technological equipment in mining have grown huge in size. Some excavators have 100 cub. m. buckets and booms 50-65 and more metres long. The load-carrying capacity of trucks used in this industry has also gone up to 40-75 and more tons. The speeds and unit productivity of metal-cutting equipment have also been multiplied.

With the growth of the unit capacity of technological assemblies there has naturally also been an increase in the

scale of enterprises and a growth in the concentration of production.

The second, exceptionally important trend in the change in working machines, which emerged and was developed to some extent in the third phase of large-scale machine production, is connected with *the development and installation of automatic machines.* This signifies the transition to a new and higher stage in the development of machines, the character of labour and the organisation of production, i.e., the transition to automation. The automation is one of the key elements in the current STR and will be considered in greater detail below.

Such are the key changes in the instruments of labour in the third phase of the development of large-scale machine production.

Advances in the natural sciences (chemistry, physics and biology), which study the nature and inner structure of substance, their use of mathematical formalism, which helps to produce quantitative definitions of the structure, uniformities of development and interaction of substances, and finally, progress in the technology used in research led to *important qualitative changes in the objects of labour.* The industrial production of man-made, synthetic materials emerged and developed fairly rapidly. By 1950, world output of synthetic resins and plastics reached 1.6 million tons, and of chemical fibres 1.7 million tons. Problems in the development of organic synthesis chemistry and the development of polymer materials are also component parts of the STR, and they will be specially considered below.

The use of the traditional objects of labour—various types of natural raw and other materials—was raised to a markedly higher level. New physico-chemical methods of working natural raw materials—coal, oil, wood, polymetallic ores, etc.—are developed and used ever more extensively, and this makes it possible to extract more and more valuable components from what used to be regarded as waste, and so to make more complex use of natural raw materials. New resources, not known or used earlier, are discovered in the old objects of labour.

The third phase in the development of large-scale machine production is also marked by important qualitative shifts in technological processes. Alongside the further inten-

sification of the traditional technological processes electro-technological and chemico-technological processes are developed and widely used.

In metallurgy, there is an intensification of technological processes through the use of oxygen in the blast-furnace, open hearth furnace, and converter processes. The share of electric steel-smelting methods is sharply increased. In metal-working, there is a gradual replacement of conventional cutting with treatment by means of plastic deformation (pressing, three-dimensional forging, etc.). Some mechanical processes give way to chemical ones, and interrupted processes to continuous ones. Advances in the manufacture of production equipment brought about the increase in the capacity of assemblies while markedly extending the use of this progressive method. There is use of fundamentally new technological processes induced by the STR.

Thus, *in the third phase there is a complete replacement of the power of steam by electricity and a tremendous increase in the unit-capacity of every type of equipment, the fusion of all the elements of the machine complex described by Marx in the modern working machine, further development and broad application of machine assemblies, fundamental progress in the technological processes, the development of every type of specialisation of production and a further spread of the mass assembly-line organisation of production. In the middle of the phase (in the 1950s), some STR-induced elements—automation of production and man-made and synthetic objects of labour—were put to use.*

Marked changes take place in the organisation and management of production both at the level of the enterprise and of the industry, owing to the following factors:

— units tend to consist of an ever greater number of parts, and technological processes of more and more operations, and this immensely complexifies the problems of combining the material and personal elements in space and time;

— the output of an ever broader range of manufactured goods for production and everyday purposes in mass batches (cars, electrical equipment, household instruments and appliances, radio goods, television sets, etc.) intensify the trend towards a deepening of every form of specialisation and cooperation in production;

— specialisation and cooperation, its inevitable concomitant, markedly complexify intra-factory, inter-factory and inter-industry ties;

— the vast pace of technical progress and the consequent ever more frequent change of the instruments and products of labour necessitate flexibility in the organisation of production.

The intricate complex of organisational problems is connected with the tasks of planning and stimulating production, the organisational structuring of the organs of management at every level of the management pyramid, the correlation between administrative and economic methods of management, etc.

The intensive mechanisation in this phase of the basic technological processes, the beginning of automation of some of them, and the emergence of computers, all of these create the prerequisites for substantially modifying the nature of work.

There is a further differentiation of workers by trade, together with the emergence and growth of more broadly specialised workers operating multi-functional machine-tools and item-specialised assemblies, and there appears a category of ancillary workers performing all the processes of movement and servicing the equipment.

The development of production makes it imperative that workers should have an ever broader general education and polytechnical training. This gradually runs into ever greater contradiction with the social foundations of the capitalist system, a contradiction which is to play an ever more important role with the advance of the STR.

In the third phase of the development of large-scale machine production, the sectoral structure of industry also undergoes important changes, is complexified and enlarged.

The product of labour, designed (at the point of its production) for satisfying very definite requirements, is the result of material production and is, in consequence, usually regarded as a passive element which is obtained from the action of the instrument of labour on the object of labour (naturally, with the given technology and the given organisation of production). But in some phases in the development of large-scale machine production, the circumstances arising with the emergence of the given product of labour from the

entrails of industrial production tended markedly to change. Some products of labour, while having been produced for solving definite problems and satisfying the concrete requirements of material production itself, were simultaneously put to totally different uses in other fields, so creating totally new requirements and, accordingly, making heightened and diverse demands on material production, technology and science. This, for its part, led to considerable changes in large-scale machine production itself, and in the development of its key elements.

One such highly important catalyst in the development of large-scale machine production was the internal combustion engine, which had been discovered back in the 19th century. It provided the basis for major technical changes in agriculture and the means of transport.

The development of industry and its growing specialisation and cooperation, together with the need to transport vast masses of primary raw materials, objects and products of labour and working people from their homes to the enterprises and back again—all of these conditions ran into contradiction with the rigid, inflexible and limited means of rail transport, which, in particular, was little suited for urban transit and which required very large capital inputs.

This contradiction was resolved by the automobile and then by air transport. In the 1930s and 1940s, the automobile industry epitomised the assembly-line production of that period and provided the ideal application for item-specialised working machines. At the same time, the motor, the aviation and then the aerospace industries acted as a unique catalyst in developing a whole range of what could be called secondary lines of production designed to service them (while being powerful and independent industries in their own right), like steel, aluminium, magnesium and titanium sheet industries, industry producing oil-refining products, rubber and tyres, plastics, etc.

The same thing happened with electric power, which initially served mainly as a source of motive power, and then began intensively to spread into everyday life, so inducing a very rapid growth of the mass production of household electrical appliances.

The defence needs provided an additional major impetus for the intensive development of new industries: tanks and

trucks, aircraft, radio communications, radar and anti-aircraft fire control, all of these made new and great demands on the automobile, aviation, electrotechnical and then also on the electronics industries.

The new industries and their new products called for new R & D. The ever faster speed of transport vehicles stimulated research into dynamics and aerodynamics. The steady increase in the speed and height of aircraft flight came into contradiction with the internal combustion engine capacity, and this led to a rapid development of basic research into processes connected with high and super-high speeds, and the development of jet engines on that basis.

The growth of the electrical and radiotechnical industry was connected with research into electricity, notably the field of low currents. Vacuum technology develops on a large scale following the invention of electronic tubes.

Thus, in close interaction between science, technology and the electrical industry at the juncture of the third and the emergent fourth phase of machine production there arose a new science—electronics—and the corresponding electronics industry. *Electronics has become one of the key components of the current STR*, and has provided a material basis for cybernetics, a new and rapidly developing science which is of tremendous importance for the advance of the STR. Cybernetics will be dealt with in greater detail in subsequent chapters.

These trends led to the development at a high and much faster rate within modern industry of the electric-power and chemical industries, and especially of oil refining and organic synthesis chemistry, the production of ferrous and nonferrous (especially light and new) metals, power, automobile and aircraft engineering, the electrotechnical and radiotechnical industries, and especially electronics and all the branches of engineering providing equipment for these leading industries. As a result, *large complexes of industries with a ramified intrasectoral structure and intricate intrasectoral proportions and ties have taken shape within modern industry: the fuel and energy industries, metallurgy, large complexes of chemical industry, engineering, etc.*

3. INTERNAL CONTRADICTIONS IN THE DEVELOPMENT OF MACHINE PRODUCTION AND WAYS OF THEIR RESOLUTION

Technical progress, as we have seen, led to qualitative changes on a tremendous scale in the growth and complexification of large-scale machine production in the third phase of its development. But this process also produced tangible internal contradictions within machine production itself, and also provided the material conditions making it possible to resolve these contradictions and so to ensure the advance of machine production to the next and higher stage.

The contradictions arose in energetics, in the instruments and objects of labour, and in the organisation and management of machine production as a whole.

In the energy field, these contradictions sprang from the fact that with the tremendous and continuing growth of requirements in energy, its production has up to now been limited to the availability and location of primary energy resources: mineral fuels and sources of hydroenergy. Apart from the limited nature of these resources, their location on the globe as a whole, and on the territory of the USSR, in particular, does not at all coincide with the location of energy consumers. This necessitates the building of costly transmission lines to carry power over large distances, and frequently induces the use of very costly and inefficient sources of energy or stimulates the building of enterprises-users in remote areas with a hard terrain where the energy sources are located, and this sharply increases the capital intensiveness of production. In addition, the contemporary techniques in the use of energy, notably the generation of electric power, has a very low efficiency and entails very great losses of energy resources.

One of the most pressing problems now is to provide the necessary quantity of energy and to make it possible to generate it in the areas where it is used. An acute need has arisen for new sources of energy which could help to solve this problem.

In the instruments of labour, these contradictions were expressed in the fact that the technical potentialities of working machines—production and other equipment—their speeds, the capability of working at critical regimes, the complexity and precision of their operations, and also their

multi-tool character and complex rigging, etc., have run into contradiction with man's limited physiological potentialities, so sharply reducing the use of the potentialities latent in modern equipment. The use in production of an ever wider range of radioactive materials has produced a number of production areas where man cannot be present at all.

The choice of the optimal, technological processes and regimes for the whole process of production now tends to become the most vital problem. At the same time, the very definition of optimal conditions and regimes tends to become an ever more intricate problem requiring the receipt and very fast processing of a vast volume of information. The solution of this problem, for its part, is constrained by man's limited potentialities and the traditional methods of management.

Thus, *the solution of these problems was increasingly incompatible with the potentialities of the working people and the traditional mid-19th century technology with which they were equipped* (*and largely still are*).

This produced the urgent need for fundamentally new means of labour to solve the ever more complicated problems in developing production, while making up for man's inherent limitations as the chief subject of material production.

The advance of large-scale machine production also produced serious contradictions connected with the limited potentialities of natural materials (both in terms of properties and technical characteristics, and in terms of available quantities and the scale on which they were extracted).

Unprecedented speeds, and the intense and critical regimes of operation of jet engines, high-parameter turbines, and heat engines operating in complex temperature conditions produced the problem of developing super-high strength materials capable of resisting fluidity, creepage, and high and low temperatures, materials with a heightened chemical stability, radiation resistance, etc. New demands on the quality characteristics of materials come from the atomic energy and the space industry.

As the work loads of current-carrying communications steadily increase, there arises the need to develop coatings for the wires and cables of electric machines and transmissions with heightened thermal and dielectric characteristics.

There has also been a marked increase in the requirements

for materials to make consumer manufactures (fibres for fabrics, leather for footwear and leather goods, etc.) and for food raw materials. Finally, the need for structural materials has grown on a tremendous scale.

The limited potentialities of natural materials have been an ever more critical constraint on the solution of materials problem.

Exceptional importance has been attached to the problem of developing materials through the use of accessible and virtually unlimited sources (taking into account the size of that input into production) of raw waterials and simultaneously of materials which do not depend on the properties of natural raw materials and have preset properties.

Important contradictions have also been growing in the whole process of organisation and management of present-day production.

The increasingly multi-operational character of technological processes and the progressing intersectoral, intrasectoral and interoperational division of labour and specialisation of production have made intersectoral, intrasectoral and intraproduction ties ever more multifaceted and important, while it was becoming ever more difficult to take these into account in the organisation and management of production, and while the economic importance of each technical and production-organisation decision tended to multiply. Working in the same direction is the complexification of technology, and their ever closer ties with the results of research, a fact which tends to diversify the possible technical solutions for one and the same production problem. At the same time, the adoption of an economically warranted decision implies the processing of a vast amount of information accumulated and processed in the course of R & D, and design, preparation, organisation and management of production. Finally, this information is also processed in the establishments servicing intra- and intersectoral ties: supply, financial, accounting and planning agencies.

Information has been intensely converted into an "object of labour" for the millions of people engaged in collecting and processing it in production and elsewhere.

The volume of the required information and the labour-intensity of its collection and processing increasingly tended to outgrow the potentialities of the number of these people and their traditional technology.

There arose the need to introduce modern and sufficiently efficient technology for the collection, processing and transmission of information and the technical equipment of the processes of organisation and management of production.

Such are the basic contradictions engendered by the inner logic of the development of production and technical progress.

The current STR, while being a natural consequence of the progress of technology and production, is also a condition for resolving the mature contradictions described above. The development of the elements of this revolution determines the advance of large-scale machine production to a qualitatively new and higher phase.

CHAPTER THREE

THE STR AND THE DEVELOPMENT OF THE NATURAL SCIENCES

1. REVOLUTION IN NATURAL SCIENCES: INITIAL AND COMPONENT PART OF THE STR

The current STR is expressed in the revolutionary changes occurring in the fundamentals of material production and its key component elements: energy, the instruments and objects of labour, techniques, and the organisation and management of production.

However, this revolution in the technical foundations of production differs substantially from all earlier technical revolutions.

Such revolutions increased mankind's mastery of the forces of nature and assured it of more productive instruments of labour (with the transition from manual tools in the epoch of manufacture to the system of large-scale factory production), more powerful and convenient sources of energy (with the transition from steam power to electric power) and more efficient materials (the use of iron instead of bronze). However, this involved the use of the available natural materials, without any radical change in the inner structure of the substance, and with the use of natural reactions developed earlier. Of course, even then technical progress rested on the use of achievements in the natural sciences—physics, notably mechanics, and also chemistry. But it did not necessitate any revolutionary changes in the natural sciences themselves.

The requirements of large-scale machine production which emerged in the 20th century, and which in the 1930s and 1940s became most acute, were much more radical, going to the very structure of substance, the basic principles on which technological processes were based, and the nature

and principles on which the instruments of labour acted on the objects of labour. Fundamentally new methods of research were required to solve such problems.

Only a revolution in the natural sciences could evidently provide the starting basis for such a technical revolution. The imperative need for a revolution in the technical foundations of production could be effected only as a scientific and technical revolution. Marx wrote: "Mankind thus inevitably sets itself only such tasks as it is able to solve, since closer examination will always show that the problem itself arises only when the material conditions for its solution are already present or at least in the course of formation."[1]

This is clearly borne out by the revolution in the natural sciences which began in the first half of the 20th century and which is still on. It was simultaneously the starting point and a component of the current STR. *The revolution in the natural sciences causes revolutionary changes in technology and production, while the results of the latter, for their part, becoming powerful instruments of modern science, stimulate and accelerate the revolutionary processes in the natural sciences.*

In the light of these complex and diverse, direct and feedback connections, I shall try in this Chapter to analyse in more concrete terms the processes arising from the revolution in the natural sciences, and in the following chapter, from the revolution in technology and the basic elements of production. But before getting down to this analysis, I must give a general description of the basic features and substance of the current STR as a whole, or its global structure, and of the conditions which determined the necessity and possibility for its origination.

The STR has been characterised from various angles. Interesting ideas about the substance and phases of the current STR have been expressed by Academician Bonifatsy Kedrov in series of articles entitled "About Scientific Revolutions".[2] In one of his articles he wrote: "One could assume that it was in the mid-20th century that the preparation for the STR was completed, and the development of the STR proper, the fourth type of scientific revolution, began."[3]

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[1] Karl Marx, *A Contribution to the Critique of Political Economy*, Moscow, 1970, p. 21.

[2] See *Nauka i zhizn*, Nos. 10, 11, 12, 1975.

[3] *Ibid.*, No. 12, 1975, p. 11.

He believes that the main feature of the STR is above all the overcoming of the lag in the development of natural science and the development of technology and production. "Another new element in the mid-20th century was the beginning of the clearly faster pace of development of modern science.... Science appeared to be blazing the key routes for future production practice. It enabled the latter to master lines whose realisation would have been altogether impossible without preliminary wide research into the whole new sphere of nature which was just being involved in the circle of man's cognitive and practical activity."[1] Accordingly, Kedrov assumes that the essence of the STR "can be correctly understood only by tracing its orientation upon the complete destruction of the old barriers separating the scientific discovery (cognition of nature and its laws), the technical invention (technical mastery of that which has been cognised by science) and the practical application of scientific and technical achievements to mass production. It is the fusion of all these three elements, their unity, that is perhaps the most important feature of the fourth type of the scientific revolution."[2]

This attempt to characterise the STR in terms of the relationship between science, technology and production is useful and interesting, but it is only one aspect of the problem. There is also a need to characterise the STR in terms of the *nature* of the processes going forward in science, technology and production. That is the aspect that is of especial importance for elaborating and solving the problems arising in the construction of the material and technical basis of communism.

Some authors have proposed something like a set of slogans to define the STR: "the atomic age", "the computer age", "the age of electronics", "the age of automation", "the polymer age", "the space age", and so on.

One fairly popular view is based on the characterisation of the STR as transition from the mechanical action of the objects of labour by cutting to new—beam, electronic, blast and other—methods.

I think that neither of the two approaches reflects the crux of the matter. In the former instance, an attempt

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[1] *Ibid.*, p. 8.

[2] The author classifies the current STR under this head.

is made to characterise a multidimensional object by means of only a few of its parameters. The choice of the definitions quoted above shows that the STR is multidimensional and has diverse aspects, and that it is multipolar. It also shows that these definitions do not fully take into account the complexity and multidimensional nature of the STR. At the same time, such definitions fail to show what is common to all these manifestations of the current STR and what it is that characterises its essence and specific features.

In the latter instance, the method of action by the instruments of labour on the objects of labour is regarded as the chief and definitive characteristic of the phase in the development of machine production, something that one cannot, of course, accept, because such a definition does not in any way cover all (or even the main) characteristics of the STR. Besides, beam and ultrasonic action is also mechanical action, for only chemical and biological action is radically different.

In an effort to characterise the essence of the current STR, one should always take into account two of its organically connected aspects: the material and technical aspect, and the social aspect. Its material potentialities create the conditions and prerequisites for solving the vital social problems facing society, while the processes connected with the STR—its directions, content and use of its potentialities—have an important socio-economic aspect. In every phase of its formation, development and realisation in social practice, man continues to be the subject of the STR, as the collective worker existing and acting under definite relations of production. These relations of production which are dominant in a given society have an effect on the goals and tasks the subject sets himself in developing science, technology and production, and they determine the lines along which society realises its production and non-production resources.

The predominant social relations can either act as an impediment, as they do under capitalism, or promote rapid and boundless development and realisation of the STR's material and technical potentialities, as they do under socialism.

In the light of the methodological remarks made above, let us now consider the STR itself.

There is no doubt that the current STR tends to introduce

fundamentally new changes into every element of material production and has key definitive characteristics with respect to each of these elements.

Each of these characteristics determines the situation in its sphere, but cannot lay claim to generalisation, to a unifying position in all the elements of production, and does not bring out the specific features of the STR as a whole.

I think that the essence and specific features of the STR lie in the radical change in mankind's relations with its environment. While continuing what is an essentially endless process of analysis and explanation of the world, mankind rises to a higher stage, increasingly adding *synthesis to analysis, control to explanation, with a tremendous growth in productivity and a radical change in the content and character of labour, a radical change in man's functions in the process of production, and a change in the nature of information and spatial and temporal connections between man and his environment.* That is characteristic of all the elements of production.

These specific features are of cardinal socio-economic importance. At the same time, the revolution in production connected with the realisation of the STR's potentialities makes the need for markedly raising the level of socialisation and concentration of production absolutely imperative. This trend, which is naturally realised under socialism, also partially makes headway under capitalism, and there it entails tremendous difficulties and a sharp aggravation of social contradictions.

In more concrete terms, the essence and specific features of the STR are expressed in a combination of the analysis and explanation of the structure of matter, substances, the nature of reactions and processes going on in the surrounding world, the structure of the processes of organic life, and the practical operation of mechanisms and machine influence on labour processes, with fundamentally different processes, like the following:

— directed *influence* on the structure of matter;

— the *synthesis* of substances with preset properties;

— artificial development and *control* of reactions in the fission and fusion of the nuclei of heavy and light elements;

— the elaboration and practical use of the theory of information, and the theory and practice of automatic control of machine systems;

— the development of automatic information-processing systems, and systems for the *automatic and automated control* of sophisticated technico-production and socio-economic complexes;

— increasingly *trained influence* on the processes of organic life.

These characteristics of the material and technical content of the current STR and the resultant radical changes in man's relations with the surrounding world determine the social characteristics of the revolution. *It not only changes technology but also creates the conditions for a radical change in the character and content of human labour. It works a radical change in man's role and in the role of science itself within the productive-forces system.*

In contrast to all the earlier technical and industrial revolutions, which multiplied only man's physical capabilities as the subject of the production process, the current STR creates diverse prerequisites for enhancing man's intellectual potentialities that are radical in scale and qualitative significance. For its part, this peculiarity of the STR turns out to be a most powerful accelerator and stimulator of its own development. From direct participation in the production cycle, man increasingly switches to control of the whole process of production, to its preparation, design, programming and functioning within the given parameters.

One highly important social effect of the STR is that it simultaneously paves the way for a marked increase in non-working and truly free time, and this, for its part, is a prerequisite for a growth in the educational and skill standards of men and women. Radical changes are also taking place in men's intellectual life: there is an immense growth in the volume and scope of information; modern means of transport and communication unprecedentedly increase man's opportunities for taking part in the most diverse events occurring in different places and at different times; a radical change occurs in the content of the habitual sets of consumer goods and services; the very nature of human requirements tends to change, etc. All these changes are greatly dynamic. In the life-time of a single generation most of the key components shaping men's way of life and living standards are changed repeatedly. The STR exerts a tremendous influence on men's spiritual, emotional and other aspects of life.

Consequently, the STR shapes the material prerequisites for a development of the productive forces, for a growth in society's scientific, technical and intellectual potential, for a development of the objective prerequisites for progress in production and advance of the subjective factor—the social working person—that makes it possible to formulate and fulfil the basic socio-economic tasks of the communist mode of production. The use of the STR's potentialities has created the conditions for building the material and technical basis of socialism and of the material and technical basis of communism in a short historical period.

Another and equally very important feature of the STR is the fundamental change in the content, role and position of science and research. The scientific revolution blends with the technical revolution, with the former playing the leading role and developing faster. It begins to play the leading role in the science—technology—production complex. Science begins to develop into a direct productive force, as production becomes more science-intensive. At the same time, science and research, which require more and more manpower and material resources, are transformed into a powerful faster-growing and independent element of social production.

Another highly important and largely definitive feature, and in many senses a prerequisite of the current STR is the fact that the *basic uniformities of the structure, transformation and development of matter, the emergence and progress of reactions, the interconnection between the structure of matter and its physical, chemical or other properties are increasingly given an ever more precise quantitative evaluation.*

The conditions which determined the need for the new STR combined with the conditions which created the prerequisites for making this revolution possible.

The revolution in the natural sciences stimulated in-depth shifts in research technology, and these, for their part, stimulated and accelerated scientific discoveries.

Thus, the new and formerly inconceivable technical facilities for astronomic research have recently led to discoveries in the Universe of a type of once unknown objects: active nuclei of galactics, quasars, etc. Academician V. A. Ambartsumyan writes: "Attempts to describe these within the framework of the fundamental theories of modern physics have come up against tremendous and possibly insuperable difficulties. This means that natural science

is on its way to recognising the inevitability of an ever stranger world."[1]

The new and ever more powerful elementary-particle accelerators—proton synchrotrons—have led to more and more discoveries, as a result of which the existing fundamental theories prove to be unsatisfactory, and there arises the need to elaborate totally new theories of elementary particles and the most general fundamental theories of modern physics.

Another and exceptionally important prerequisite of the revolution in natural science is *the intrusion of mathematics and mathematical methods into every area of the natural sciences.* Mathematics has become the basis for formulating the key uniformities in physics, chemistry and biology; it is being increasingly used in the social sciences as well. The "mathematisation" of all the sciences has deep roots in the basic trends in the development of science, while being a powerful catalyst of this development.

I have already said that one of the key features of the current STR is the transition from qualitative analysis to a quantitatively-definitive influence, to synthesis and control of processes. In order to control a process, to reproduce it, to create substances or change their structure and properties, there is a need to determine the quantitative proportions of the actual structures and the quantitative parameters of processes, to find the quantitatively definitive connections between the characteristics of the structure of substances and processes and their properties and results, and this cannot be done without the use of mathematics. The need to use ever more intricate mathematical formalism is also connected with the appearance of the objects of scientific research which frequently lie beyond conventional notions.

Thus, modern physics explores objects like stellar associations, quasars, etc., which have a mass that is many times greater than the mass of the Sun, with metagalactical distances measured in tens of billions of trillions (10^{27}) kilometres, with periods of time coming to 10^{17} seconds, or to tens of billions of years. Both in physics and in biology there is a study of micro-objects with intervals of 10^{-16} cm and 10^{-26} second.

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[1] *Vestnik Akademii Nauk SSSR*, No. 3, 1971, p. 29.

The interpretation of such objects, phenomena and events evidently calls for an unusually intricate mathematical formalism, and new images and concepts.

There is brilliant confirmation of the idea which Lenin expressed at the very beginning of this revolution in natural science, when he said: "Human thought goes endlessly deeper from appearance to essence, from essence of the first order, as it were, to essence of the second order, and so on *without end.*"[1]

An ever greater number of phenomena and processes in theoretical physics, chemistry, biology, mechanics, technology, economics, sociology and medicine require the use of the theory of probability and other mathematical methods. The mass involvement of mathematics in research has stimulated radical changes in mathematics itself, and here we also have a kind of chain reaction.

Here is a description of this process by Academician B. V. Gnedenko: "One must say that the recent period has contributed especially much not only to the development of mathematics in breadth and increase of its connections with other scientific disciplines, but also to bringing out the in-depth inner connections between the branches of mathematics itself, which not so long ago were regarded as totally different mathematical sciences. It has also been invariably established that the broader approach, the consideration of a big generalised conception as a rule leads to a more economical mode of reasoning. And this happens not only because many results can be obtained at one go but also because the deep logical analysis of concepts with which one has to deal makes it possible more swiftly to discover the desired interconnection."[2]

Further shall deal with the problems arising from the use of electronic computers. At this point let me note merely that one of the expressions of the chain reaction between the development of mathematics and the revolution in the natural sciences has been the creation, rapid improvement and introduction into every branch of science and the economy of electronic computing (and also modelling) facilities. *Computers have tremendously expanded the possibilities for*

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[1] V. I. Lenin, *Collected Works*, Vol. 38, p. 251.

[2] *Science and Mankind*, Moscow, Znanie Publishers, 1962, p. 111 (in Russian).

using mathematics, while promoting progress in some mathematical sciences.

Below I shall try to give an idea of the material content of these revolutionary processes going on in the natural sciences and already exerting a visible (or foreseeable) direct or indirect influence on technology, material production, and the economy as a whole.

Within the framework of this book it is impossible to consider the whole natural-science complex, which is why I have selected four groups of fundamental sciences: a) physics, b) chemistry, c) biology and e) processes of control and cybernetics. I intend to consider these sciences in the light of their influence on the economy and the socio-economic processes in the life of society.

2. THE PHYSICAL SCIENCES

There is no doubt that the current revolution in natural science was started by physics and the physicists. The brilliant discoveries and the rapid advance of the physical sciences, especially since the Second World War, gave a powerful impetus to the development and radical change in all the other natural sciences.

The inevitable penetration of physics into every branch of natural science is largely due to the fact that it makes a study both of the simplest and of the most common properties of matter. Physics is quite rightly called "the mother of mechanics". Progress in the physical sciences has an immediate influence on all the basic elements of modern production: energy, and the instruments of labour and techniques. Solid-state physics has a growing influence on the instruments of labour (raw and other materials). This is most evident nowadays, when we have been witnessing the emergence of atomic and nuclear energy and technology, electronic and laser technology, semiconductor and integral circuits, etc.

It is no exaggeration to say that the advances in the physical sciences provided a starting point for the development of very many basic sciences (especially those emerging at the conjunction of the chemical and physical, and the biological and physical sciences) and many of the main engineering disciplines.

Progress in physics has a great influence on the whole of the modern world-view, chiefly because of the close connection between physics and the theory of cognition. Fundamental departments of modern physics like the theory of the structure of matter, the theory of relativity and quantum mechanics are organically connected with the theory of cognition. This was pointed out by Lenin in his *Materialism and Empirio-Criticism*, in which he analysed the state of physics and drew the conclusion that modern physics tended to engender dialectical materialism.[1]

Let us recall that Lenin regarded the advances in physics over the last three decades of the 19th century and the early years of the 20th century as gigantic and breathtaking. It is more than six decades since the publication of his *Materialism and Empirio-Criticism* in which he gave this assessment. We have good ground to say that the changes in this field since then are even greater and truly revolutionary.

The revolutionary changes in physics ran along several closely interacting lines. A key role belonged to the new fundamental theories radically changing the most general notions concerning the nature of phenomena taking place in the surrounding world. These theories made it possible to take a new look (and a very fruitful one it was) at the phenomena and processes going forward in the microworld (on the level of the atom and elementary particles) and in the macroworld, including cosmological problems.

A very important direction which determined the radical revolutionary changes in the fundamentals of physics consisted of the tremendous advances in technical facilities used in physical research and experiments.

Of course, Albert Einstein's special and general theory of relativity and the theory of quantum mechanics were the fundamental theories which provided the most important basis for the current scientific revolution in physics and largely in all the other natural sciences. They had the definitive role to play in the advance from classical physics to the new, so-called relativity physics, i.e., the physics based on the theory of relativity.

Marx's well-known dictum formulated in his "Theses on Feuerbach"—"the philosophers have only *interpreted*

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[1] See V. I. Lenin, *Collected Works*, Vol. 14, p. 313.

the world in various ways; the point is to *change* it"[1]—could also be applied to those working in the natural sciences: physicists, chemists and biologists. The STR, as the term itself implies, eliminates the shortcoming noted by Marx. The combination of science and technology itself testifies to the fact that a scientific discovery, i.e., explanation, is transformed into a technical solution, i.e., an active change of reality.

Indeed, the giants of thought who shaped the beginnings of the current STR took the characteristic attitude of blending theory with being, with active influence on the processes going forward in reality, and this is impressively epitomised by the works of Einstein. He proved that it follows from the relativity of space, time and motion that the mass of a body depends on its velocity, and so on the energy of its motion. When a body approaches the extreme speed of 300,000 km. per second—its mass tends to infinity. Einstein's suggestion that the mass of a body at rest also depends on its inner energy E was also of vast importance. That was the basis of the energetics of the STR. It turned out that if energy and mass were to be measured in conventional units, energy was equal to mass multiplied by the square of the velocity of light, c, that is $E = m \cdot c^2$.

Three million times more energy is generated by the fission of uranium nuclei than in the chemical reaction of fuel combustion (1 gr. of uranium produces more heat than 3 tons of burnt coal). But that is only a small part of the energy corresponding to the whole mass of the substance. Thermonuclear energy already uses a roughly 10 times greater share of the internal energy of particles as compared with the atomic energetics of the fission of heavy nuclei.

Einstein's formula opens up even grander horizons in the use of nuclear energy, and is latent with subsequent stages of the STR in energetics. The following simple arithmetical calculations will show the full energy potentialities of matter which spring from Einstein's formula.

According to Einstein's formula, energy equals mass (let us say 1 gr.), multiplied by the square of the velocity of light, c. The velocity of light is equal to 300,000 km/sec,

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[1] Karl Marx, Frederick Engels, *Collected Works*, Vol. 5, p. 5.

or $3 \cdot 10^{10}$ cm/sec. Consequently, $c^2 = 9 \cdot 10^{20}$ cm/sec. Multiplying the mass in grams by c^2, we obtain the energy it contains in ergs. One kwh is equal to $3.6 \cdot 10^{13}$ ergs, which means that the total energy latent in 1 gram of matter is equal to $9 \cdot 10^{20}$ ergs, and divided by $3.6 \cdot 10^{13}$ is equal to $2.5 \cdot 10^7$ kwh (or 25 million kwh).

Of the reactions known at present, the full realisation of this energy can be obtained only from the collision of matter and anti-matter, i.e., in the so-called reaction of annihilation. It has been established that in the collision of any particle with a corresponding anti-particle they are annihilated, i.e., they disappear, while their energy and mass are transformed into energy, and fully so (as in radiation) without any breach of the law of preservation, i.e., with the full realisation of the whole of the energy according to Einstein's formula $E = m \cdot c^2$. This is thousands of times greater than the quantity of the energy generated per unit of mass in nuclear reactions.

Thus, the revolution in physics is latent with revolutions in technology and in the whole of material production.

Quantum mechanics is another line in the scientific revolution in physics, which is closely connected with nuclear physics and atomic energetics, and it heralds revolutionary changes in technology and production.

The processes leading to the fission and fusion of nuclei could be understood only with the help of quantum notions. Quantum mechanics was the theoretical basis for the development of electronics and subsequently of lasers—quantum generators of light—i.e., the fundamental basis for an already visible revolutionary change in the technology of production.

Laser radiation has tremendous potentialities.

The properties of laser radiation—the possibility of focusing a beam in a very small volume of matter—make it possible in the presence of a thermonuclear target (a compound of deuterium and tritium) to create conditions for thermonuclear reactions, involving temperatures of tens of millions of degrees and a density of fuel that is hundreds of times bigger than the density of solids. That is one of the highly promising lines in the development of thermonuclear energetics.

There is much promise in the use of laser technology in creating optical methods for processing information and

fast optical computers. This involves the substitution of optical means—wave beam guides—for cables and wires and the creation of an efficient and fast optical "memory" of great volume for electronic computers and a constant memory-store for information systems.

All these ideas and discoveries have produced the theoretical basis for unprecedented progress in radio engineering and a triumphal advance of electronics, which has permeated and continues to permeate every branch of hardware and progressive types of technology.

> Highly instructive here is the influence which physics, notably quantum theory, has exerted on the chemical sciences. Mendeleyev's periodic system, which was largely an empirical law of chemistry, has been provided with sound theoretical foundations by the development of quantum mechanics and the establishment of the quantum model of the atom. It has turned out that the arrangement of the elements which Mendeleyev discovered has a highly important yet very simple physical meaning. The serial element in Mendeleyev's system (physicists call it atomic number) is equal to the number of positive charges, or, in other words, to the number of protons in the nucleus of the atoms of this element. Mendeleyev's law has become one of the laws of atomic and nuclear physics.
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> The use of quantum theory opens up tremendous potentialities for solid-state physics in acting on the fundamental properties of metals and crystals generally. The quantum properties of solids make it possible to use crystals as diverse physical instruments. The study of physical phenomena in thin semiconductor films has provided the basis for obtaining integral, hybrid and functional circuits, and this is directly connected with the miniaturisation and micro-miniaturisation of electronic devices and the development of the latest generations of computers.

That is far from a full picture of the scientific revolution in 20th-century physics. Everything that has been said above relates to the scientific discoveries that have already been made and to their obvious importance for hardware and material production.

But the revolution in physics continues. Its potentialities are multiplied many times over by the powerful facilities going to equip research in physics.

One need only point to the Soviet experimental installations in plasma physics—Tokamak-3, and the even more powerful Tokamak-10. Soviet physicists obtained the world's best results in heating plasma up to 7 million degrees with a density of the plasma column of 10^{12} particles per cubic centimetre, a state in which it was maintained on Tokamak-3 for several hundreds of a second. There is every reason to expect that Tokamak-10 will help to raise the temperature and the density of the plasma, together with the time of its maintenance close to the parameters required for the start of a self-sustaining thermonuclear reaction in the chamber. At the same time, physicists are also searching for other ways of heating up the plasma to the level required for the start of thermonuclear reactions.

Cecil Frank Powell, an English physicist, a Nobel Prize winner and a guest member of the USSR Academy of Sciences, wrote that the recently discovered astronomical objects like quasars and exploding galaxies are a source of tremendous energy, estimated to be of the order of 10^{62} ergs (i.e., three times more than the full energy of matter according to Einstein's theory). The existence of such sources of energy can no longer be interpreted within the framework of conventional nuclear processes. Highly intriguing uniformities have also been established, he says, among the newly discovered particles. He expresses the hope that over the next century mankind will be able to comprehend these discoveries and create new sources of energy many times more productive than nuclear sources.[1]

The fantastic density of matter and, consequently inconceivable at present, energy potentialities are connected with so-called "black holes".

For many years scientists in various countries have theoretically predicted the existence in space of such "black holes",

[1] See *Nauka i zhizn*, No. 10, 1969, p. 15.

collapses of matter. Astronomers at the Kitt Peak observatory in Arisona, the United States, discovered at the centre of Galaxy M-87, within the Constellation of Virgo, a "dark object" with a very high density: the mass of that object was 5 billion times greater than that of the Sun. Almost simultaneously, astronomers at the Observatory on Mount Palomar in California recorded at the centre of the same galaxy a glow of such radiance that could be produced only by stars collapsed together by the gravitational force of matter with a tremendous mass at their centre. Scientists assumed that this mass could be a "black hole" exceeding the Solar System in proportion. There, the density of matter is such that a few cubic centimetres of it weigh about 1 billion tons.

The penetration by physicists using ever more sophisticated facilities in physical research and experiments into the depth of the micro- and macro-world poses new problems which are of global and fundamental importance.

"One could say," says Academician A. Logunov, Vice-President of the USSR Academy of Sciences, "that the general conception of the world as an aggregation of various forms of organisation of matter is largely determined by the advances in studying the micro-world."

Successes in the construction of charged particles accelerators for ever greater energies (now measured in hundreds of billions of electron-volts) have helped to obtain very important data which have produced fundamental problems whose solution will open up before mankind new and grand potentialities. Academician Logunov says: "There is, first of all, the problem of the structure of strongly interacting particles (adrons), of which the best known are the proton and the neutron. Their properties and systematics are now well described on the basis of the hypothesis of sub-elementary particles—quarks...

"It is quite possible that the energies attained with modern accelerators are simply inadequate for the generation of free quarks not connected into adrons. If this assumption is confirmed, it will mean the possibility of processes with a release of energy in the elementary act hundreds or thousands of times greater than in conventional nuclear reactions, i.e., the prospect of a gigantic leap forward in the energy potentialities of the Universe and perhaps of mankind as well.

"Another group of problems arises from low interaction. It could be of fundamental importance not only for understanding the microstructure of matter, but also of the spatial and time structure of our world and possibly also for cosmology. It could turn out, for instance, that the solution of the basic problems in the structure of matter will require a review of the basic notions concerning time and space, and that with the advance into the depth of the microworld processes now appearing to be inconceivable will become possible."[1]

Physicists believe that new phenomena of fundamental importance could arise when particles are approximated to a distance of 10^{-16}—10^{-17} cm., which corresponds to an energy of about 300 billion electron-volts within the centre of inertia of the colliding particles. That is why work is going on in the USSR to design an acceleration-accumulation complex on the basis of the Serpukhov accelerator to obtain protons with an energy of 2,000-5,000 billion electron-volts.

Once again, unprecedented potentialities "with the collision of heavy nuclei", says Academician Logunov, "should produce phenomena of the type of shock waves under whose impact nuclear matter could be converted into unusual states." Soviet theorists point in this connection to the possibility of the existence of new forms of nuclear matter which is distinct from the atomic nuclei we know. "The study of such predictable theories of super-dense, super-heavy and possibly purely neutron nuclei holds promise of opening up fundamentally new ways of studying the forces and energy latent in them, which means a return to the beginnings which could shape whole new stages in the scientific and technical revolution."

Simultaneously, derivatives of all these acceleration techniques are practical events of a purely industrial application. Here are briefly some of them:

— bunches of accelerated particles exert on many materials a highly specific effect not to be obtained by other means;

[1] A. Logunov, "Into the Depths of Matter", *Izvestia*, December 22, 1976.

— sources of gamma-radiation, electronic accelerators are broadly used to sterilise products in the medical industry, to effect the radiation polymerisation for the insulation of cables, for flaw-detection in large engineering products, etc.;

— powerful bunches of electrons, up to one million Amperes, are being used in research into regulated thermonuclear synthesis;

— heavy accelerated ions can be used to produce molecular-virus filters by irradiation of plastic films for the de-contamination of water by means of simple filtration, etc.

Those are only some of the possibilities in physics. Similar scientific quest is naturally under way in every field of science. This study of the indepth secrets of matter could lead to fundamental changes in the existing notions of the nature and uniformities of the surrounding world, and could open up fresh potentialities for technological re-equipment of production.

3. THE CHEMICAL SCIENCES

The revolution in the chemical sciences has developed, on the one hand, autonomously, within the field itself, and on the other, under the strongest influence of the latest trends in physics, quantum physics, in the first place.

At the turn of the century, Dalton formulated the atomic theory of the structure of matter, and the development of this theory established the concept of the molecule consisting of atoms as the simplest particle of matter carrying its chemical properties.

What remained unclear was the order in which the atoms were arranged in the molecule. The prominent Soviet chemist, Academician A. N. Nesmeyanov says: "One should recall the formula of the organic substance $C_{40}H_{82}$, and it will become clear that the molecular formula is only an 'inventory' of the content of the molecule, and not its plan. It took the whole of the third half of the 19th century to understand the principles on which molecules were structured from atoms."[1]

[1] *The Scientist's View*, Collection of Articles, Moscow, USSR Academy of Sciences Press, 1963, p. 391 (in Russian).

In 1861, the Russian scientist A. M. Butlerov produced the theory which showed the architectural plan of organic molecules. This theory was a most important basis of the revolution in organic chemistry which began at that time and is continuing in the 20th century.

Two fundamental discoveries preceded the scientific understanding of the archirecture of molecules: the way to determine molecular weight (the weight of the molecule relative to the weight of the lightest of the atoms, the hydrogen atom) and the concept of the valency of elements, i.e., the number of standard atoms with which the atom of the given element is capable of bonding to form a stable compound. This led to the formulation of the laws on which molecules were structured and laid the theoretical foundations for the chemical synthesis of matter. The synthetic chemist—according to Academician Nesmeyanov's simile, is the architect of the microworld, and it is here, in the synthesis and control of the properties of substances that one of the characteristic features of the current STR lies.

It was organic chemists who chiefly became "molecular architects". This is connected above all with the fact that the number of organic, carbon compounds known at the present time is probably at least 20 times greater than the number of inorganic compounds of all the other 100 elements and runs to about 2 million. The diversity of these compounds is virtually boundless. Thus, 40 atoms of carbon and 82 atoms of hydrogen can help to structure 62.5 trillion (6.25×10^{13}) molecules differing in architecture, each of which is the tiniest unit of a special substance.[1]

These revolutionary changes in chemical science itself went hand in hand with active introduction into chemistry of new theories and potentialities brought about by modern, non-classical physics, a development which chiefly brought to chemistry the theoretical explanation of many empirically established uniformities.

Academician I. V. Obreimov refers to this peculiar fact: "One of Niels Bohr's followers asked him what Bohr regarded as the most remarkable in the history of physics. Bohr replied that he was most amazed by the fact that the early organic chemists, who laid the foundation of this science, reached

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[1] *Ibid.*, p. 390.

correct conclusions concerning the form of organic molecules."[1]

Anticipating my exposition somewhat, let me say that the revolution in chemistry is connected with the control of the structural molecules and, accordingly, with the production of substances with preset structures and properties, i.e., the development of directed chemical ties. That is where the introduction and use of the latest physical views had a key role to play. It turned out in the mid-20th century that not only did the moving electron produce a magnetic field, but also that the static electron is an elementary magnet and has a complex of properties which enable it to be a vehicle of chemical bonds. This role of the electron determines a whole complex of the most important phenomena in crystal chemistry, including control of the crystal lattice of substances, control of semiconductor and dielectric properties, formation of totally new chemical compounds, etc.

The possibility of structuring molecules and substances naturally required a further indepth study of the architecture of the existing substances and molecules and of the interconnection between it and the basic properties of substance, and also of the ways for acting on the architecture of molecules. It was necessary more intensively to learn architecture from nature, the great architect.

Homologous series, a phenomenon specific to organic chemistry, and isomerism, a characteristic phenomenon, make it possible actually to plan the boundless structuring of molecules.

These amazing properties of matter—the dependence of the key properties of matter on the geometrical arrangement of the same atoms in space (within molecules) have produced a whole science of the spatial arrangement of atoms in the molecule and the influence of this geometrical factor on the properties of matter, known as stereochemistry, a science whose emergence was anticipated in the 19th century by Butlerov.

The all-round cognition of the structure and uniformities of the surrounding world equipped mankind, technology and production with the possibility of directed and balanced production of substances and materials with preset properties which men required.

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[1] *Ibid.*, p. 273.

Consequently, the scientific revolution helps to solve the problem of the objects of labour, one of the most important foundations of material production.

Here is an exhaustive extract from an article by Academician Nesmeyanov which is brilliant in content and form and helps to characterise the practice and potentialities of synthesis: "Now and again the structure of molecules of a natural compound was established and its synthesis first effected through an intricate and costly way, and then by ever simpler and cheaper ways, until, finally, the industrial production of the given compound proved to be cheaper than its extraction from natural sources. Then the consumer begins to receive only the synthetic product, while the production of the natural product ceases. This happened... with indigo and alizarine, salicylic acid and rubber. Then, the plan of the molecule of the artificially obtained substance is modified to produce a whole complex of kindred substances, and among them even more valuable and interesting substances than their natural analogues. Now and again, conversely, among the purely synthetic compounds will be found substances which are important for this or that field of application but without any prototypes in nature. That is what happened with aniline dyes and explosive substances. What are the limits to the power of synthesis? The answer one should give is—there are none. All the substances capable of existence can be obtained by synthesis. The only limits are economic. But these differ with each epoch, and with the extension of the potentialities and perfection of industrial synthesis they are steadily expanded."[1]

The advances of theoretical chemistry, the use in chemistry of the revolutionary accomplishments in physics have tremendously extended the range of problems successfully tackled by the chemical sciences. Chemistry ranges over ever new spheres of the organic and inorganic world, penetrating into a number of related sciences, shaping new inter-face, sciences, while being enriched with their methods and conclusions and simultaneously enriching them.

This will be seen from the following new lines.

Organic-element chemistry, which lies at the conjunction of organic and inorganic chemistry. It has paved the way for

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[1] *Ibid.*, p. 452.

the development of whole families of new polymers of organometallic and organosilicon compounds with properties totally inconceivable earlier on, and also for the possibility of introducing new and immensely more simple and economical technological methods for obtaining polymers.

Complex-compound chemistry, which has made it possible to discover a numerous class of new chemical compounds. It has helped to develop the industry of precious metals and to solve the chemical aspects of atomic energetics. Complex-compound chemistry has the definitive role in producing efficient chemico-technological processes for the working of raw materials.

Geochemistry, or the chemistry of the Earth, whose analysis of the substance and processes going on in the Earth rests on chemical laws and methods. This science studies the chemical evolution of our planet and seeks to explain, on a chemical basis, the origins and history of the Earth, its outer layers, relief, mountains, seas and oceans.

Physico-chemical mechanics, which combines the mechanical and electrical properties of substances with their chemical composition and structure.

Electrochemistry, a department of physical chemistry analysing the properties of systems containing ions and of processes involving ions going forward along the boundaries of such systems with other bodies, metals in particular. Electrochemistry includes everything that relates to the connection between electrical and chemical phenomena.

Biochemistry studies the structure of proteins and protein molecules, the functions of enzymes, the synthesis of protein in the organism, and the relations between the chemical structure and the biological functions (activity) of proteins. Biochemistry also studies important and complex processes like immunity and the immune properties of proteins.

Radiochemistry is closely connected with solving the problems of radioactivity, radio isotopes and the use of atomic energy.

Chemical physics, whose task is to apply the achievements in modern physics to the basic problems of chemistry, namely, the structure of atoms and molecules and the study of the inner mechanism of chemical reactions.

Chemical kinetics, the science of chemical transformations, studying the velocity and lines of chemical reactions. It is connected with the development of the general theory of

chain processes and the discovery of the possibilities of controlling chemical chain reactions.

Solid-state chemistry is another promising branch of chemical science which has been developing in the Soviet Union over the past few years. Scientists in Leningrad have classified the chemical transformations of solids and have developed a new chemical method, that of molecular deposition. In this area, it has become possible to effect controlled synthesis. Solids are obtained by depositing one atom upon another, just as living nature does it.

In the laboratories of the chemistry of solids department at the Leningrad technological institute, atoms of iron and titanium, nickel, phosphorus and carbon are deposited in a preset order. Automatic installations have already been designed to deposit super-fine films on semiconductors.

Over the long term, this method could radically modify the whole process of the manufacture of, say, tube production.

Agrochemistry has a tremendous role to play in the life of mankind today. The Soviet agrochemical school was founded by Academician D. N. Pryanishnikov. Of key importance was here the clarification of the role of soil conditions, the study of the nutrition of plants and the shaping of the crop within the complex system of plant—fertilizer—soil, Pryanishnikov's famous triangle.

The key conditions for boosting the productivity of agriculture are nitrogen, phosphorus and potassium nutrition of plants, the chalking of soils, the operation of microelements, the use of microfertilizers and the connection of all of this with crop rotation and selection.

> The Soviet Union leads the world in the production of mineral fertilizers. In 1975, according to the Minister of the Chemical Industry of the USSR, an increase in fertilizers by 28 million tons (in conventional units) helped to obtain additionally farm produce worth 5.5 billion rubles: 16.1 million tons of cereals, 6 million tons of potatoes, 25.3 million tons of sugar beet, and 600,000 tons of cotton and flax—a net income of 3.4 billion rubles. The use of plant protectors has helped on an average annually to save 18.9 million tons of cereals, 9.6 million tons of sugar beet, 1.3 million tons of raw cotton, 5.5 million tons of fruits and berries, a total worth nearly 4 billion rubles, with total inputs

into chemical protectors amounting to 450-500 million rubles.

For their part, the advances in the chemical sciences have a tremendous impact on the truly revolutionary processes in the biological sciences. On a physico-chemical basis, biologists have ever more vigorously and effectively sought to cognise the complex processes going on in the living organism.

The directives of the 25th Congress of the CPSU on the development of the chemical sciences emphasised the need "to extend research in the field of chemical compound synthesis for obtaining new substances and materials that have new properties, to develop new chemical processes with highly efficient catalytic systems that largely speed up chemical reactions, and to develop scientific principles for technologies utilising mainly closed cycles."[1] These questions are also dealt with extensively in the Guidelines for the Economic and Social Development of the USSR for 1981-1985 and the Period up to 1990.

4. THE BIOLOGICAL SCIENCES

A real revolution has been stimulated in the biological sciences by the use of the tremendously increased research facilities and the latest discoveries in physics, chemistry and mathematical methods. Molecular biology has revolutionised the science of the living world to the same extent as quantum theory revolutionised nuclear physics 40 years ago.

The intensive study of the biological functions of living beings on the strength of molecular structure and molecular interactions has determined the *leading role of biochemistry and of molecular biology, a relatively new science.*

Analysis shows that each physiological process—breathing and photosynthesis, sight and sense of smell, and most importantly, movement and development—have their own complex inner structure and organisation. *Of fundamental importance for the development of biological science has been the establishment of the catalytic principle of the functioning*

[1] *Documents and Resolutions. XXVth Congress of the CPSU*, p. 233.

of living matter. The discovery established that all or nearly all reactions going on in organisms are effected with the aid of catalysts with a strictly specific function. These catalysts have been designated as enzymes, and their importance will be seen from the fact that Academician A. N. Bakh has called them "the keys of life".

"We are now aware," says the Soviet Academician A. Braunstein, "that enzymes surpass artificial catalysts immensely in many respects. First of all, there is the force of action. Thousands of chemical reactions go on in living organisms with the involvement of enzymes without high temperatures and pressures, and proceed millions and even billions of times faster than they do in the presence of the best chemical catalysts.

"Enzymes have another advantage, the most important one. They differ from artificial catalysts in the amazing rationality of their action, which is strictly oriented and efficient to the utmost. Each enzyme operates optimally, without seeking 'optimal technological solutions', and transforming only one or a group of kindred compounds, and does this in a strictly definite direction."

The discovery and description of new biochemical reactions made it necessary to clarify the fundamental principles determining their nature and interaction, as otherwise any systemic understanding of vital processes and reduction of the countless biochemical components into comprehensive systems were inconceivable.

The solution of these problems was initially connected with two fundamental discoveries made in the 1930s and 1940s, which largely determined the revolution in the biological sciences, especially on the biochemical level. The first of these was the *discovery of the "conservation" of the energy of biochemical reactions* in the form of special chemical bonds in substances, which has been designated as adenosintriphosphate (ATPh). The second was a *discovery of the principle of the conjugation of reactions in biological systems*, under which in parallel reactions the excess of energy arising in one of these could be transferred to another reaction without which the latter would have been impossible on its own. Academician A. Kursanov says: "These two fundamental discoveries at once introduced logic into the quest for the organisation of the biochemical activity of cells helping to make a distinction between energet-

ically feasible and unfeasible combinations of reactions. This marked the start of the collection of biochemical parts into separate blocks and whole mechanisms, and when the work was completed in a definite sector it turned out that researchers had succeeded in putting parts together into this or that physiological process which biochemists had started to work out some 30 years earlier."[1]

These theoretical advances were already of considerable practical importance, making it possible efficiently and purposefully to exert an influence on physiological processes. Biological principles have long been extensively used in the microbiological industry and pharmacology for the production of medicinal substances aimed to activate or slow down definite physiological processes.

The subsequent progress of science and the ever deeper penetration into the secrets of life revealed processes which were more complex than photosynthesis and breathing, and for whose understanding biochemistry proved to be inadequate. These were above all the processes of growth and development, and also heredity and its transfer.

The properties of living matter underlying these phenomena were not to be discovered either by physiological or biochemical methods and experiments. It was the emergence of electron microscopes that made it possible to penetrate into these intricacies, into the world of infinitely small particles of the living cell. In this way, the *practical results of the revolution in physics provided a powerful catalyst for the revolution in biology.* While conventional microscopes had a resolution of 2,000-3,000, the electron microscope makes it possible to enlarge objects hundreds of thousands and even more than millions of times. Quantity had developed into quality: fundamentally new potentialities appeared for the study of the finest organisation and the most intimate processes going on in the living cell.

These complex studies, Academician Kursanov said, made it possible to clarify the role of the mysterious actors the electron microscope had brought onto the biological scene.

It was established that the basic genetic information, or the potential capacity of species for exercising various physiological functions was ingrained in each organism in its

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[1] *Nauka i zhizn*, No. 7, 1970, p. 8.

DNA (desoxyribonucleic acid), which is concentrated in the nucleus of the cell.

Biological science, penetrating ever deeper into the secrets of vital processes, discovered the mechanism underlying the use of genetic information. In this way, biological science came to a study of gigantic molecules of biopolymers, like nucleic acids, proteins and some hydrocarbons, which have the crucial role to play in the vital functions. A study of these molecules required special methods, and these constituted one of the basic subjects of the new and rapidly developing science—molecular biology—of which more below.

Today, the advances in biological chemistry are highly powerful instruments for the cognition of vital processes, but the language of chemistry has turned out to be inadequate for penetrating into the secrets of life. Accordingly, *biophysics* has come on the scene. Subsequent efforts in solving the problem of living substance are of tremendous methodological and practical importance for advancing and perfecting material production.

Academician G. M. Frank writes: "What we conceptualise as the 'living' defies deciphering only in purely chemical language. Apart from the list of the reactions involved in the chemical processes of metabolism, catalysts of reactions and chemical kinetics of these processes, there is also a need for *some organisation in space* (*structure*) *of large molecular complexes* which goes beyond purely chemical notions."[1] It is highly important to emphasise that this is nothing like an elementary, stable structure and organisation given once and for all. Its distinctive feature is flexibility and continuous adaptability for the best solution of the numerous problems which arise in the course of vital processes. Frank adds: "This organisation is not only a place in which chemical processes proceed; it itself acts, changes and determines their organised course. That is why apart from chemistry and molecular approaches there is also a need, tentatively speaking, for a 'supra-molecular approaches'. These can no longer fall only within the ambit of chemistry and biochemistry. At this point, qualitatively new processes arise and, in addition to the chemical forces of interaction, phenomena enter into play which are characteristic of some complex 'supra-molecular' system. Such phenomena are

[1] *The Scientist's View*, p. 580.

usually considered by *biophysics* or *physico-chemical biology*."[1]

The biological sciences naturally devote especial attention to the activity of living organisms and their tiniest components on the level of the cell and of the components of the cell itself. Hence the penetration by science into the sub-microscopic structure of the cell which has produced the most unexpected discoveries inducing a radical review of many earlier notions about the biochemical, biophysical and physico-chemical foundations of cellular processes.

Vital phenomena are not connected with individual or isolated cells but with the organism as a whole. With the exception of unicellular organisms, in which the cell is specially adapted to an autonomous existence, tissue cells cannot have a fully valid isolated existence. That is why as soon as we begin to penetrate into vital processes, cells and their content appear to us in their inner and external interconnections, i.e., in their structural and organisational aspect. Only by in-depth understanding this mechanism is it possible to comprehend the substance of vital processes. And that is the starting point for learning to influence vital processes and then for governing them, for learning to imitate and reproduce them.

Molecular biology, a new science, which has produced a number of brilliant results in a short period, is closely connected with the above-mentioned fields of biological science.

"The task of molecular biology", says Academician V. A. Engelgardt, the most prominent scientist in this field, "is to study the key manifestations of vital activity at their primitive, elementary levels: in the cell and in its parts, in the nucleus and the citoplasm, in the tiniest intracellular structures, in the most primitive systems existing on the very boundary line between the organic and inorganic, like viruses and bacteriophages, and finally, in the systems of the high-molecular biological polymers—proteins and nucleic acids—which perform the key functions in living entities...

"There has been especially intensive development of molecular-biological research into the problems of breeding, heredity, the structure and properties of high-molecular compounds, their biosynthesis and the uniformities of their reproduction, cell-fission and divsion."[2]

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[1] *The Scientist's View*, p. 580.
[2] *Ibid.*, p. 558.

High-molecular biopolymers, like proteins and nucleic acids, are the chief objects studied by molecular biology.

In 1953, James Watson and Francis Crick produced a model of the secondary structure of DNA, the so-called "double helix", which gave the clue to many secrets of nature. In 1970, 17 years later, Har Gobind Khorana, an Indian scientist working in the United States, synthesised from simple chemical compounds a section of this helix, the first artificial gene containing the record of a part of the hereditary information of yeast. Almost simultaneously, a most important and convincing experiment was staged at Oxford. The nucleus was removed from a fertilised ovule of a frog and substituted by another extracted from an intestine cell of a different species of frog. This combined embryon grew into a frog which did not resemble the mother but the frog to which the transplanted nucleus had belonged. The DNA, transplanted with the nucleus, the above mentioned double helix, dictated the plan in accordance with which the young organism developed. What is especially remarkable is that the double helix was not taken from the sex cell, but from an intestine cell. This showed that the whole genetic information, the whole data for the development of the species were recorded in the DNA of any cell, be it a sex or any other specialised cell.

It the late 1950s, the Nobel Prize was awarded for the synthesis of the hormone of the back part of the pituitary body. The biologically active adrenocorticotropic hormone was synthesised in 1961. The 1960s yielded exhaustive information about the amino acid sequence in such key elements as the haemoglobin of the blood and the myoglobin of muscles. Another discovery revealed the primitive structure of the enzyme, a ribonuclease protein.

The discovery of the nature and structure of nucleic acids showed very well the exceptionally rational character of nature and organisation of its beings. Indeed, nucleic acids consist only of four elements, nucleotides, which differ from each other only by their nitrogene base: adenine, guanine, cytosine and thymine. Thus, the whole diversity of life on the Earth rests on a totally unique and universal

biochemical basis, a truly astounding level of unification and rational "organisation of production". Combinations of these four elements account for all the innumerable and diverse properties of heredity and their action. It has been established, moreover, that in a molecule of DNA the quantity of guanine is always equal to the quantity of cytosine, and the quantity of adenine to that of thymine.

The DNA double helix also turned out to be equally universal for all organic matter. Wherever the helix is found, its structure is always based on the principle of complementarity. Such is one of the most important foundations of molecular biology, the *priciple of complementarity, which explains the age-old secret of heredity.*

Whereas only four elements are used in structuring nucleic acids, nature has been more generous in producing proteins ("Life is the mode of existence of protein bodies", as Engels put it[1]). Here 20 elements known as amino acids are involved. The plan on which each protein is structured is determined by the arrangement of nucleotides in the DNA. Molecular biologists have established that three consecutively linked nucleotides correspond to one definite amino acid. Consequently, the DNA helix is the hereditary plan for the structuring of future organisms. That is how the protein-synthesis mechanism functions, and its discovery has been one of the major achievements of the revolution in the biological sciences.

The DNA molecules in which hereditary information is coded have a remarkable "repair technique".

Scientists have established that under the impact of internal and external influences DNA molecules involved in metabolism are variously damaged in the process of the organism's vital activity. Stable injuries to the DNA molecule structure lead to mutations, i.e., changes in the heredity of the new organism. But in fact that does not happen, for the organism "repairs" the molecules. Biologists and geneticists have established that in the course of metabolism which constantly goes on in the cell, enzymes remove a great number of injuries from DNA molecules. According to Academician N. I. Dubinin, the well-known Soviet geneticist,

[1] Frederick Engels, *Dialectics of Nature*, Moscow, 1972, p. 301.

this remarkable repair job is done by four enzymes

The first of these—the endonuclease—keeps moving along the double helix of molecules as if probing for the regularity of the structure. Having discovered any damage, this enzyme makes an incision in the chain first before the injury and then after it.

The second enzyme—the exonuclease—widens the breach which has arisen in place of the sector excised from one of the chains of the spiral.

The third enzyme—the polymerase—fills up the breach in accordance with a similar sector from the neighbouring chain of the molecule.

The fourth enzyme—ligase—re-establishes the bonds between the newly built up sector and the main chain of the DNA.

In this way the "repair team" of enzymes eliminates any impediments to the transfer of heredity.

The ever more active role of science, which is a characteristic feature of the current STR, is expressed in the fact that biologists seek to give a precise definition of the various enzymes and the possibilities for exerting an influence on their operation.

Seeking to clarify the structure and functions of enzymes, science wants to find ways of directing physiological processes in practice and discovering new ways of protecting living organisms from noxious influences.

Academician Braunstein writes that over 500 congenital effects in human metabolism are now known, and these spring from hereditary, genetically rooted disruptions in the synthesis of a given enzyme. Thus, the congenital absence of an enzyme accelerating the final stage of the biosynthesis of the amino acid tyrosine results in a sharp disruption of physical and mental development among children. Defects in the formation of some enzymes of sugar metabolism result in disruptions in the stability of blood cells.

The unsurpassed selectivity in the operation of enzymes makes them invaluable reagents for biochemical analysis.

The current STR is far from over, it is gaining in depth and breadth, revealing ever new facets and potentialities, and this probably applies most of all to the biological sciences. Its visible successes here are only a small part of what will gradually become everyday practice in human life and

the life of society as a whole. This is clearly seen from molecular biology. For all the tempestuous and brilliant successes of the new science (which is perhaps no more than two decades old), the advanced contingent of molecular biologists are already moving ahead to new and still totally unprobed areas.

The new lines in the development and further highly *revolutionary advances in molecular biology have deep general methodological roots.*

This involves the organic and highly fruitful synthesis of two methodological approaches: the resolution of the complex into ever more simple component parts and the study of their nature and properties, and the study of the structure, organisation and properties of the complex object as a whole, and of the forces and processes going to create this coherent system.

The basic question is how the complex springs from the primitive, what are the forces and uniformities operating here and producing the new properties of the complex system.

The idea is to orient research in such a way, according to Academician Engelgardt, "as to move from the most primitive and basically elementary molecular levels... in the opposite direction, to levels of ever growing complexity of organisation, to systems acquiring new properties and functions."[1]

Integration is the basic feature of this transition from the primitive to the complex, and accordingly Academician Engelgardt has proposed that this line of research should be designated as "integratism".

The development of the natural, technical and social sciences and of their methodology and practice reveals many common characteristics.

Thus, the above-mentioned methodological approach is absolutely necessary both in developing automatic systems and in elaborating the overwhelming majority of complex programmes, because the gist of it is the solution of problems arising from the relation between the part and the whole, the complex and the primitive. This methodological approach is most meaningful and necessary in the formulation of decisions for economic and socio-economic problems and

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[1] *Nauka i zhizn*, No. 5, 1971, p. 11.

programmes in which we always have to deal with large complex and multi-component systems.

This explains the importance of the problem of "integratism" for all the natural, technical and social sciences. There is good reason why the theory of systems and the systems approach are so high on the list of instruments under the current STR. Nor is it surprising that among the most prominent theorists and creators of the systems theory we find the biologists Ludwig von Bertalanffy and economist Kenneth Boulding. Even the early penetration by biologists into the secret processes of vital activity revealed, alongside the diversity and complexity of these processes, the supercomplexity of their structure and organisation and also the great efficiency and economy of "living production" which is for the time being inconceivable in material production.

It has become obvious that if makind succeeds in fully deciphering the structure and organisation of organic life and can influence, reproduce and use them in practice, this will open up two gigantic and, one could say, high-road lines in the development and perfection of material productive forces.

First, *mankind will be able to exert a directed influence on organic life and on that basis vastly to enhance the efficiency of social production, and also to increase the potentialities and bring about a marked perfection of man himself, society's primary productive force.*

Second, *society will be able constantly to apply to production "the structural and organisational accomplishments of organic life," and on that basis to ensure another scientific and technical revolution which, judging by everything, will be a great advance in all the potentialities latent in the current STR.*

Biologists and physiologists, biochemists and biophysicists, molecular biologists and geneticists, all these contingents of scientists have been probing for the secrets of life from various angles, and making more and more advances in mastering and governing the forces and potentialities of nature. The revolution in the biological sciences has demonstrated the "hardware", "technology" and "organisation" of functioning systems which are much more complex than any of those ever created by man, and which, for the time being, have a productivity that is unprecedented anywhere in the practice of world industry, while being inconceivably

compact, miniature (much more so than any miniaturisation), economical and reliable. These systems and principles are material and cognisable; consequently, they can be reproduced. Over the past two decades biology has brilliantly demonstrated that they are cognisable.

The active phase in the current revolution in the biological sciences began somewhat later than it did in physics and chemistry so that its active practical results may not yet be as great and obvious, but it is already evident that the cognitive and practical potentialities which will be opened up through the revolution in the biological sciences are so great and broad in scope that they may provide the starting point for another scientific and technical revolution.

5. THEORY OF SYSTEMS, PROBLEMS OF INFORMATION, CONTROL AND CYBERNETICS

We have already seen from many examples that the advance of the revolution in the natural sciences has its own inexorable logic and complex dialectical interaction. A common feature in the development of the natural sciences is the urge for so comprehending the structure of substances, reactions and processes, so analysing it quantitatively and qualitatively, as to make it possible to *govern* them, i.e., to effect a purposeful *synthesis* of substances, *to change and shape their structure and to control reactions.*

But people, as a rule, select for purposeful synthesis, shaping and control that which is required "in the social production of their existence", as Marx put it,[1] which means materials, technical systems, technological solutions and lines, and final products for production and non-production purposes. All of these objects are complex and, as a rule, large systems. As it was shown earlier on, complex systems are dealt with by physics, chemistry, biology and, of course, social sciences, technology and production at the higher stage of their development.

There naturally arises the *need for a systems approach to the solution of problems and, accordingly, the need to elab-*

[1] Karl Marx, *A Contribution to the Critique of Political Economy*, Moscow, 1970, p. 20.

orate a theory of systems and systems analysis. As these systems are shaped there arises the need at every stage—research, development and engineering—to collect, process and issue large and ever growing flows of information. Alongside matter and energy, *information acquires ever greater importance and is becoming an object of labour and a product of labour for a great and ever growing mass of people.*

There is a steady growth in the flows of information required for the development of science, technology and production, and the task of processing and mastering it is becoming ever more complicated and labour-intensive. There emerges what Stanislaw Lem called the "information barrier". Hence the need for a theory of information and for a theoretical comprehension of the problems of control, especially of large systems.

That is the origin of the now rapidly growing and closely interconnected branches of science which have an exceptional role to play in the current STR: *the theory of information, the theory of big systems and systems analysis, the theory of control and the closely related cybernetics*, "the science of control and communication in nature and society."

This produced the need for specialists in the theory of systems, control engineering, and so on.

Only with a knowledge of the theory of information, systems analysis and systems approach, of system structure and principles of its organisation, only with cybernetics, the theory of control in nature and society, have the natural—and now also the social—sciences been able to go on from explanation and analysis to control and synthesis, and that, as I have said, is the most characteristic feature of the current STR.

Ever since mankind entered the era of civilisation, it has had to do with big systems requiring control in the course of which various information is collected and processed. What then has changed in this field under the present STR? There are, at least, four main changes.

First, there has been a gigantic growth in the scale of systems (natural, technical and social) which are the objects of man's influence, and accordingly, the scale and complexity of the tasks and processes in controlling them. The flow of information to be processed has grown immensely.

Second, society itself began to create ever more complex and diverse systems, notably technical systems, among

which self-controlling automatic systems have a growing role to play. This called for in-depth research into the principles of systems functioning, the movement of information within them, and the principles and methods of control.

Third, advances in molecular biology and its transition to the above-mentioned integratism made it necessary to study the accumulation, storage and transmission of information, to analyse the functioning of living systems and to understand their inner structure, their biophysical and biochemical nature, their inner logic and the control processes in them.

Fourth, scientific and technical progress has paved the way for the creation and broad use of facilities for the processing of information and development of control devices.

Thus, *the development of this complex of sciences and cybernetics, their generalising element, was a key component and largely generalising element of the current revolution in the natural sciences and technology.*

The theory of information and the theory of control, together with the concepts they introduced—"input" (the aggregate information obtained which can be used for exerting an influence on the external world), "output" (the information which ensures this influence), "memory" (receptacle of data accumulated earlier or of data characterising normative programmes for the functioning of the given systems) and finally, the especially fruitful concept of "feed-back" (the control of a system not on the strength of its expected performance, but on the strength of actual performance)—all of these constitute the basis not only for these theories but also for new automatic and cybernetic technology.

An especially important contribution to the development of information and control problems has been made by cybernetics in connection with its establishment of the feed-back principle. The latter is of great cognitive and practical importance, and is universal, i.e., it applies to mechanisms, living beings, and complex production and socio-economic systems.

Feed-back occurs in any functioning system. It consists, first, in the coming in information about the course and conditions of the system's functioning, and the arising deviations and impediments; second, in the processing of this information and its comparison with the programme, and third, in the output and movement of the controlling infor-

mation which helps to bring the system into conformity with the actual (including changing) conditions in which it has to exist and develop, and fulfilment of its necessary functions.

The feed-back mechanism includes not only the mechanism of information movement, but also the aggregation of technical and other devices which are called servomechanisms, from the simplest to the most complex, material and spiritual, operating physically, mechanically and in the form of stimuli, and which convert this information into the required action.

The feed-back principle also has other far-reaching consequences. According to Norbert Wiener, if the information coming in as a result of the machine's fulfilment or nonfulfilment of its tasks is capable of changing the general methods and forms in which these tasks are performed, we obtain a process which can be justifiably called a process of teaching.

The complex of research in the theory of information also turned out to be directly connected with *modelling*, a very important line of research and a powerful instrument for research, development and control. The elaboration of models reflecting the key structural features of a system, the establishment of analogous ties between the elements of "input" and "output", establishment of the quantitative parameters describing these elements, and finally, imitation of the functioning of the system, and on that basis, its optimal control. Those are only some of the potentialities opening up through the use of modelling.

This makes it perfectly obvious that modelling has tremendous potentialities for solving the fundamental problems of the chemical and biological sciences, including the modelling of the work of the human brain, muscles, heart, etc., the work of large technical and production systems (say, energy systems), systems for controlling technological processes, especially in continuous production (oil refining, chemistry, metallurgy, etc.) and also the operation of large economic systems.

The theory of modelling has provided the basis for the development of electronic modelling systems and machines.

Together with the fundamental elaboration of the systems theory, the theory of information and cybernetics, there was an intensive effort to develop the *theory of automatic regulation and control.* Specialists believe that the modern theory of automatic regulation dates from the 1940s. The

ever more extensive use of automatic devices called for methods enabling researchers, developers and engineers to establish, when calculating or designing systems, the influence of various parameters on the dynamic properties of the systems and the selection of optimal parameters. There was a need not only to make the operation of the system itself stable, but also to enhance the indicators of the quality of regulation: speed, precision, etc.

The more extensive the use of automatic machines in practice, the greater the importance attached to the "sensitivity" of automatic regulation systems, i.e., the problems arising from the dependence of the dynamic properties of an automatic system on any change in the parameters, however insignificant.

This shaped a complex of sciences which constitute the basis of modern scientific methods of control and management. The solution of these problems required the setting of the goal of control to which the operations of the given system were subordinated; definition of the algorithm in accordance with which the system organised its operations; consideration of the interaction with the environment, which has an effect on the advance of the system towards the given goal; precise and timely apprehension, processing and transmission of the information about the environment and the state of the process on the basis of which control is being performed.

It would be misleading to assume that the problem of controlling complex systems boils down to the processing and transmission of information, for, in this case, some systems for the electronic processing of information are regarded as automatic control systems. Actually, the process of control includes decision-taking, an exceptionally important element. This is a complex process because it frequently involves probability, for the decision is often taken in the presence of far from full information and various other disturbances.

The current STR has generated a number of scientific disciplines whose use helps to take the best decisions, among them operations analysis, operations research, the theory of games, and the theory of mass services. Adjacent to them are linear and dynamic programming and the theory of optimal planning. All these sciences make broad use of mathematical methods and electronic modelling and computing devices.

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Above we considered the current revolution in natural science. We started out with the revolution in physics, the generally recognised leader in this process, which has had an exceptional impact on the development of all the natural sciences, and ended with the biological sciences which are ever more obviously becoming the leader in the clearly foreseeable new stage of the scientific revolution.

In conclusion, we touched upon a group of mainly methodological sciences: the theory of systems, information, control and cybernetics, whose development is a necessary condition for completing and actively realising in practice all the accomplishments of the natural sciences.

This analysis, I think, has borne out the characterisation of the revolution in natural science, formulated at the beginning of this chapter, as a transition from the analysis and explanation of natural phenomena, the structure of substances and reactions, to the synthesis and control of the properties of substances, their structure, and reactions, and finally, to purposeful influence on the processes in organic life.

6. SCIENCE BECOMES A DIRECT PRODUCTIVE FORCE

The revolution in the natural sciences described above and the consequent changes in production techniques lead to a radical change in the role of science in material production and to its conversion into a productive force in its own right.

Science began to penetrate into production virtually together with the use of machines and complex machine technology. But then it was limited to the use of the laws of mechanics in the design of machines, and elementary laws of physics and chemistry for technological processes which mainly took shape empirically.

Over a long period, science and production appeared to develop along parallel lines. On the one hand, science had yet to reach the state at which it had the capacity of exerting a direct and radical influence on production and transforming it. On the other hand, production had yet to rise

to the level at which it could no longer do with empirical knowledge alone and at which the direct use of the main advances in the fundamental and applied sciences became imperative.

In the 20th century, especially in the middle of it, the situation underwent a marked change. The development of the material productive forces, and the progress of large-scale machine production made urgent the need for revolutionary changes in all the elements of production, and these were possible only through the direct use of the basic results in scientific development.

This *inclusion of science into production was prepared by the whole development and interaction between production and man.* Man, being the prime productive force, enters into interaction with nature and with machines, and here he fulfils a number of physical and material functions and acts as a material productive force. But that is not the whole of his role in production. While participating in it as a material productive force, man also makes use of his intellectual potentialities. He comprehends the process of production, designs and improves the product of his labour, creates and perfects the means of production, the instruments of labour in the first place. While comprehending and summing up his own experience, man naturally makes use of the accumulated scientific potential and this results in an interaction between production and science which enriches them both.

Material production and its resources shape and develop its own material basis, and also the material basis of the fundamental and applied sciences, the services, and the dissemination of spiritual values. The more powerful the resources at the disposal of science, the more successful its experimental tests and honing, and the more rapid and effective the introduction of new technology into material production.

At the same time, flows of information about fundamentally new facts and ideas produced by the basic sciences, which go to increase society's intellectual potential, reach the applied sciences, and are from there transmitted into the sphere of material production, so promoting its growth, progress and expansion.

The information functions which ensure man's purposeful activity are among the chief channels along which science is involved in production.

Substantial changes in the relation between science and production are now already quite obvious. This concerns science in the first place. The STR has called for a powerful and technically well equipped industrial production base for science, as otherwise it would have been impossible to synthesise substances, and artificially generate and control various processes and reactions. The synthesis of substances with definite properties and the control of reactions already amount, in character and content, to material production or its laboratory model.

For its part, production, based on the results of such research, is, in effect, the material embodiment of scientific research, but on a much larger scale. The radical changes in the field of science itself will also be seen from the fact that the new technology and the fundamentally new products of labour are first made, tested and approved directly in the research establishments with the use of their production facilities.

Simultaneously, the STR and the scale of modern production frequently dictate the organisational merger of scientific facilities with production units. More and more experimental projects are carried out directly at the large enterprises, in the sphere of production.

According to statistics, in the USSR, since 1940, the inputs into research by production establishments working on the principle of economic calculus (excluding funds from the state budget) have multiplied over a hundredfold, from 50 million to 5.2 billion rubles. From 1967 to 1973, the number of laboratories at industrial enterprises increased by 34 per cent, the size of their personnel by 41 per cent; the number of design divisions by 34 per cent, the size of their personnel by 36 per cent; the number of pilot shops by 31 per cent, sections by 33 per cent, and their personnel by 38 per cent. In addition, the number of design, development and engineering organisations with their own balance-sheet went up by 43 per cent, and the size of their personnel by 46 per cent.

Research is becoming an ever more necessary stage in the radical technical transformations and the basis for introducing fundamentally new instruments and objects of labour and progressive technological methods and processes, and the emergence of new technical areas and industries. Thus, *science increasingly penetrates every element of modern production.*

In terms of the instruments of labour, this is expressed in the fact that the diverse types of new facilities are being developed directly as a result of the materialisation of various scientific discoveries, as in ultrasonic, electroerosion and beam machine-tools, super-high pressure presses for obtaining artificial diamonds, etc.

Automation trends are producing a situation in which man begins to emerge from the direct participation in the process of production so that he himself has to react less and less to the disturbances and complications arising in the course of production. Marx wrote: "Labour no longer appears so much as included in the process of production as labour under which man increasingly relates to the process of production as its controller and regulator."[1]

Who is then taking over from man in the process of production itself to link up the chains of direct and feedback connections? It is science, materialised in automatic control devices. Let us add right away that this new role of science does not in any sense take man out of the sphere of production. There is no doubt that he himself will always design and create the new hardware and technology, programme the automatic devices and organise and improve the technological processes.

Science, materialised in new, highly productive instruments of labour, becomes a source for multiplying the social product and the national wealth. Marx said: "With the development of large-scale industry, the creation of real wealth becomes less dependent on working time and on the quantity of expended labour than on the power of the agents which are set in motion in the course of the working time and which themselves, for their part...do not at all correspond to the direct working time required for their production, but rather depend on the general level of science and technical progress, or on the use of this science in production. (The development of science itself, and especially natural science, and together with it of all the other sciences as well, corresponds, for its part, to the development of material production)."[2]

A large and ever growing part of the objects of labour consists of the products of chemical synthesis. Science, as we

[1] Karl Marx, *Gründrisse der Kritik der Politischen Ökonomie*, *Moscow*, 1939, *S*. 592.

[2] *Ibid.*

know, gradually comes to have the capacity not only for artificially reproducing the substances existing in nature, but also for creating substances not to be found in nature and possessing pre-set properties. Science clarifies the nature and mechanism underlying the formation of geological structures, creates powerful means for penetrating into thick layers of rock, brings about progress in ways of dressing natural materials and their treatment which makes it possible to use many raw-material resources once regarded as too poor and economically unworkable. In this way science, in effect, opens up for production tremendous additional natural resources.

Modern science tackles the problem of controlling the processes of structure-formation and the development of materials with pre-set mechanical properties. Scientists working in the field of solid-state physics believe that the potential strength of metals is dozens and hundreds of times greater than that which has been technically achieved in practice, and this is borne out by experience, which gives ground for assuming that over the next few years the strength of metals will at least double. This is tantamount to considerably increasing the scale of production.

Biology, physiology and genetics have been gaining ever more knowledge about the processes going on in animal and vegetable organisms, and have in many instances substantially modified the technology of agricultural production. In this way science gradually becomes an organic part of agricultural production as well.

Nowadays, in every branch of production, processing tends to become an expanding reproduction of scientific research. One need merely recall the numerous types of chemical, electrical, electrophysical and laser technology in which scientific discoveries are embodied in the technological process.

Consequently, just as the instruments and objects of labour fabricated and developed by man came to be alongside man himself component elements of the productive forces, so *science, while still an element of spiritual culture, a spiritual phenomenon, a form of social consciousness, is becoming a direct productive force before our very eyes.* Let us add that there is a steady extension of the range of the sciences directly entering technology and production.

Should one draw the conclusion that science is becoming a fourth element of the productive forces? I do not think so.

While operating as a spiritual (ideal) productive force, in the form of knowledge realised by man, science functions as a direct productive force, being embodied in the material elements of production, the instruments and objects of labour, and the techniques and organisation of production.

At the same time, science, as I showed in Chapter One, exerts a very strong influence on man, the prime productive force, determining and multiplying his creative physical and intellectual capabilities and potentialities. Being a direct product of these, it creates, in its turn, the most favourable conditions of their realisation.

Consequently, science works a substantial change in the role of each element of the production process. Man increasingly acts—and will continue to act—as the creator of designs, technologies and programmes, as the organiser of production maintaining all its elements in working capacity through the use of his scientific knowledge. Technology will increasingly become akin to research which completes its transition to the stage of application in production. The instruments of labour will increasingly reproduce, on an industrial scale, the scientific facilities used in research and simultaneously serving as the means for the making of new products. In this already visible prospect, science, acting in its technological application to production, embodied in the instruments and objects of labour, in techniques, and in the experience and skills of the working people involved in production, permeates all its elements to such an extent that it can be with good reason regarded as a direct productive force.

Under capitalism, science, becoming a direct productive force, finds itself at the sovereign disposal of monopoly capital and the imperialist state, which use it largely for military purposes and for intensifying the working people's expoitation. Marx wrote: "Only the working class can convert science from an instrument of class rule into a popular force... Science can only play its genuine part in the Republic of Labour".[1] It is socialism and communism that create the best conditions for making use of these science-permeated productive forces.

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[1] Karl Marx and Frederick Engels, *On the Paris Commune*, Moscow, 1971, p. 162.

CHAPTER FOUR

THE STR AND MATERIAL PRODUCTION

1. THE STR'S REALISATION IN SOCIAL PRODUCTION: SOME CHARACTERISTICS

We are contemporaries of and participants in the shaping of a new stage in the development of large-scale machine production in the course of which the material and technical basis of communism is being built up in the USSR. It stands to reason that one has to comprehend the logic underlying the development of this stage and to conceive of its optimal content and the ways and means to be used in exerting an influence on its formation.

In Chapter Two I described the three stages in the development of large-scale machine production. At the third stage, which took shape in the middle of this century, many elements of production were already taking shape under the influence of the current STR. Automation, cybernetics, polymers, atomic electric-power stations and a number of fundamentally new types of technology were all applied in various sectors of material production, but all these components of the STR did not become an overriding feature, which is why they naturally did not determine the actual face of production, and perhaps do not do so even today.

This chapter contains an analysis of the STR's current impact and its even greater impact over the long term on the basic elements of material production and the change in their character and functions.

Any characterisation of a given stage in the development of material production includes only the scientific and technical innovations which have already become organic components of production, determine its face, are dominant or are becoming such in its crucial sectors. Such an approach makes it obvious that *the main features of the present stage*

in the development of production, which began gradually to take shape in the second half of the 20th century, *cannot as yet be regarded as being identical with all the potentialities of the STR*, above all for the two following reasons. First, the staggered development in time of the basic lines of the STR and the different duration for the various lines of the stages of research, development and engineering. Second, the inertia and the influence of the existing scientific notions, the available production facilities, techniques, etc.

On the basis of a more detailed consideration of these reasons, let's try to characterise the change trends in the basic elements of large-scale machine production.

How do the main lines of the STR take shape in time, and what influence will they have on material production over the next few decades?

At every given moment in science, technology and production, there are *three consecutive echelons of problems.*

The first consists of scientific and technical problems which have already been solved in principle in scientific and technical terms and in the initial stages of production before the start of the current or projected period. In the period being considered, these solutions can obviously be mastered and applied in production on a fairly extensive scale. Consequently, they will exert the definitive influence on the basic scientific and technical characteristics of production and also on its economic parameters.

> Today, these are uranium-based atomic power stations; many types of automatic instruments of labour, including units with automatic numerical control; new methods for the hardening of metals and other structural materials, methods for synthesising polymer materials, the production of artificial diamonds, etc; continuous casters for rolling steel, the production use of laser technology; the use of third and fourth-generation word processing computers controlling some production processes and in some instances even whole works.

The second echelon consists of problems which have been solved in scientific terms, but which have yet to be finally developed, although their development is fully feasible in the current (projected) period. The tasks of this period consist in finding the technical solutions and getting down to

their engineering. Over the next two or three decades, these will evidently begin to exert an influence on production but will not determine its face.

The third echelon consists of scientific problems which are already being tackled and which, according to competent expert assessments will undoubtedly be solved, but which for the time being have not been solved even at the stage of research and experiments. That is why it is impossible to lay down any date for their realisation and application in production.

> These scientific problems are to some extent exemplified by thermonuclear energetics; the cracking and the possible practical use of the genetic code; the discovery and establishment of ways for using in production the principles on which systemic functions are regulated in living organisms, and so on.

These three groups of problems relate to basic scientific discoveries and technical solutions which at various stages will result in marked changes in the leading sectors of material production.

Let us consider the second reason for the inevitable distinctions between the basic features of the emergent fourth stage in the development of machine production and the potentialities of the STR. As I have said, it consists in the power of inertia. Experience shows that very important technical and technological innovations are connected with the use of the existing traditional scientific and technical facilities.

The inertia of existing technical facilities springs above all from the tremendous bulk of the existing production assets. Let us recall that on January 1, 1978, the USSR had fixed production assets in the economy worth 934 billion rubles. Even with the high rate of growth of fixed assets[1] which is characteristic of the Soviet economy, the share of

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[1] According to 1976 data provided by the Central Statistical Board under the USSR Council of Ministers, the introduction of new fixed assets (their active part, i.e., machinery and equipment) cameto 9.6 per cent of year-end assets, and their withdrawal for reasons of wear and tear to 2.3 per cent of assets at the beginning of the year.

old assets (available at the beginning of 1971) made up nearly 60 per cent of all assets at the end of 1975, and while this figure will be reduced by the end of 1980 it will still be fairly large—almost 30 per cent.[1] Here one should bear in mind that a sizable part of the new assets frequently consists of the same traditional hardware, and this goes further to intensify its power of inertia. Analysis shows that traditional hardware and technology also make up a sizable share of the components in many new technical development projects.

Consequently, over the next one or two decades, the role of technology materialised before the beginning of the 1970s will be very considerable and will, accordingly, have an essential impact on the nature of material production.

Finally, research projects and their embodiment in technology and application in production require a considerable time, which must have an effect on the basic characteristics of material production.

The current STR creates the conditions for a fundamental change in the relations between science, technology and production.

There is *growing integration of science, technology and production, and a reduction in the time lag between scientific discoveries and their materialisation in production.*

But such trends do not in any way minimise the need for utmost efforts to reduce the period of scientific and technical progress from the scientific discovery to its application in production. This fully applies to all the three echelons of progress considered above.

> Thus, it takes 15 years to realise new scientific and technical solutions in production, which relate to the first echelon, and that in countries where scientific and technical progress is relatively faster. Erich Jantsch says that this is a kind of "incubation period" in the course of which, many prognosticators believe, extensive technological application is made of scientific discoveries.

That is the general view of the prospects for the development of basic elements of production.

[1] Within ten years, just over one-third—36.1 per cent—is to be withdrawn from the assets available at the beginning of this decade.

Before going on to a consideration of each of these, one has to characterise the general changes in their composition and structure which have occurred and which are still going forward under the impact of scientific and technical progress.

The Marxist view of the productive forces is that they are an aggregate of the means of production, i.e., the means and objects of labour, and the working man.

Scientific and technical progress substantially enriches and extends the range of elements making up the means of production, shapes and develops a markedly modified and enriched composition of the means of production and, accordingly, changes the functional structure of social production itself.

This relates most of all to the means of labour. A considerable influence on the characteristics of the means of labour is exerted by changes in the sectoral structure of production. By the start of the Tenth Five-Year period in the USSR, almost 40 per cent of the fixed production assets in industry were concentrated in the electric-power industry, ferrous metallurgy, oil refining, and the chemical and petrochemical industries, i.e., sectors where the means of labour are either large units in which mechanical energy is transformed into electrical energy, or capacities in which thermal, electrical or chemical energy is used to transform matter.[1]

These units and capacities radically differ from the classical means of labour described in the well-known chapter on the development of machines in Volume I of *Capital*. In some of these, one type of energy (heat, the movement of water, the energy produced by the fission of the nuclei of heavy elements, and subsequently the synthesis of the nuclei of light elements) is transformed into mechanical and then into electrical energy (or back into thermal energy). At electric-power stations, there are evidently no traditional means of labour acting on objects of labour. Turbo-generators, which are usually regarded as the means of labour operate only as a means for the transformation of energy, it is not they but the energy of heat, water or the atom that acts on them, so producing electrical energy as output. Consequently, it is the energy of the primary energy-carrier that exerts

[1] The figure is even higher with nonferrous metallurgy, the cement industry and a number of food industries.

the action, sets the turbine in motion and stimulates the production of another type of energy.

To return to the original stage of the cycle—the production of energy of the primary energy-carrier, heat or atomic energy—there again it is energy that operates as the means of labour and acts on the mineral fuel (coal, oil or gas) or on atomic fuel, so resulting in the combustion of fuel or in the heating up of plasma in the thermo-nuclear energetics of the future. In atomic energetics, we do not even find this traditional action, because it is the critical mass of uranium (or plutonium) that acts as the stimulator for the release of the energy of nuclear fission.

By contrast, there is an object of labour in metallurgical, chemical, oil-refining and similar units, or capacities, in the form of the metallurgical charge, the chemical raw materials or crude oil, but it is once again energy, heat or electricity—in electrometallurgy and electrochemistry—that operates as the instrument of labour acting on this object and transforming it into other substances. The processes of this type are being ever more broadly introduced in other industries, notably, engineering.

Alongside of this, there are already in existence processes and lines of production—and in the foreseeable future they are bound to increase at a high and priority rate—in which the energy of biological processes, also acting in capacity units, operates as the active means of labour. It is precisely in the sphere of these units and capacity assemblies, used to transform energy and substance, that the increase in unit capacity is most intensive. Industries and lines of production with such units are most in need of automation and the optimisation of technological processes and control of these processes at that optimum level, its highest form; at the same time, these industries are most adapted to this kind of automation.

Technological processes in these industries run under the influence of numerous variable parameters which are beyond the capacity of man, as the governing subject, to record and optimally combine, which is why they require automatic modelling, recording and control, and that is a very difficult task. Let us recall that up until recently, the blast-furnace process altogether defied mathematical formalisation. But it is this complex of industries that provides the basis for shaping an automatic system of machines adequate to the

current STR and the material and technical basis of communism.

The development and rapid advance of this category of means of labour has far-reaching socio-economic consequences. First, they bring about a radical change in the content and character of labour, for the operators do not, in effect, take a direct part in the process of production. They control the uninterrupted operation of the units, maintain them in a working condition, control and regulate the supply of energy and substance and, accordingly, the output of the energy and substance produced. To do this, they keep track of an intricate system of control and measuring instruments with a feedback effect. With the advance of mechanisation and automation of ancillary and auxiliary processes, this work becomes ever more akin to that of engineers. This is truly a realisation of Marx's prediction that man will become an observer and controller of the production process.

Second, means of labour of this type, whose unit capacity has been rapidly growing, are serviced by a relative handful of personnel and, accordingly, have a much higher productivity than in the traditional industries, thereby helping to boost labour productivity in industry as a whole.

There is also a substantial change in the means of labour in the traditional industries (with discrete type of processes and products), like engineering, wood-working, textiles, garments, and so on. These changes are connected, first, with a re-distribution of functions among the industries turning out the objects of labour and industries turning out the final product. Scientific and technical progress has induced the first group to turn out on an ever growing scale blanks which in form approximate the final article. This trend helps to reduce the number of operations which have to be performed in the manufacturing industries, thereby making it possible to produce means of labour effecting almost simultaneously the whole or nearly the whole complex of operations required to obtain the finished product.

Changes in the traditional instruments of labour are also connected with the advance of automation and the gradual switch to a three-element automatic machine system: working automatic machines—cybernetic modelling and controlling devices—system of servomechanisms effecting direct and feedback connections between the two former elements. The ever more extensive use of numerical control devices lends

this system the flexibility which is required under the fast pace of technical progress. In the foreseeable future, automatic manipulators—robots doing more and more of the arduous and monotonous operations—will gain in importance within the instruments of labour system.

I described the *objects of labour* in Paragraph 4 of this Chapter and will merely note here that under the impact of scientific and technical progress many materials which are usually classified as objects of labour begin to act on technological and organic processes, so helping to intensify them, i.e., operate in a sense as instruments of labour. One need merely cite chemical fertilizers, catalysts and enzymes, biological stimulators and oxygen and their action in some technological processes.

The changes in the structure of social production are a reflection of deepening division of labour, a process which, under the impact of scientific and technical progress, leads to specialisation and a gradual separation of some functions and lines of production. The new functional elements of the means of production no longer quite fit either with the means of labour or the objects of labour. Among them one could identify the following: energy, information, technology and research facilities.

Energy. When listing the elements of production (in the epoch in which steam energy was prevalent) Marx did not regard energy as an independent element of the process of production and designated the source of energy, "the motor mechanism" (i.e., the steam engine), as a component part of the contemporary machine system connected with the working machine (tool) by means of cumbersome belt drives, the "transmitting mechanism". The rapid growth of the energy-intensiveness of production in the 20th century has radically changed the nature of energy, the modes of its production and the ways of its use. Heat and energy have become the products of highly specialised industries. The motor mechanism has disappeared from the machine system. It and the transmitting mechanism have given way to electric motors and the individual electric drive built into the working machine. What is especially important is that energy has come ever more explicitly to perform four different functions: motive force, source of heat and light, and ever more extensively and actively the functions of instruments of labour directly acting on the objects of labour or on

the transformer of energy (like a turbo-generator) and helping to yield the final product. A similar role is being ever more extensively played by the energy of chemical processes, as the energy of biological processes is bound to play in the foreseeable future. All of this gives ground for identifying energy as an independent element of the means of production.

Information. This has always been a necessary element of any production process. Scientific and technical progress and the attendant growth of the scale, and of the all-round development and improvement of production, the steady advance in the division of labour and specialisation exert a substantial influence on information—its volume, content, and place in the organisation of production, and also on the organisation, methods and techniques by means of which it is processed and used.

The complexification and improvement of the products of labour, the instruments of labour and techniques make it necessary ever more stringently to observe the numerous technical and operational parameters of the equipment and materials being used, of the course of the production process itself, and of the intermediate and final characteristics of the products being fabricated. This is reflected in the growth of a numerous army of controllers and laboratory assistants and in the very much faster growth of instrument-making.1

Aongside purely technical information, modern production requires the processing of a growing volume of scientific, design, technological, organisational and managerial information. Automation and optimisation of production regimes, the operation of technological units, lines of production, sections, shops and even larger systems require the processing of vast volumes of information. There is a steady growth in the volume of information required to regulate the ever more complex ties within the factory, sector and between sectors in modern production.

As the volume and scale on which information is used increase, the shaping and processing of information are increasingly specialised and set apart. In production, and especially so in design and management, information increasingly becomes the object and product of the labour of specialised workers. At the same time, there has been intensive technical equipment of the collection, processing and trans-

mission of information, a steady extension in the use of special cybernetic information hardware, and, accordingly, the shaping of special industry for the processing and storage of information, together with a special communications industry which, in the foreseeable future, is bound to be integrated with information facilities to ensure the centralised distribution and delivery of information. Alongside the instruments and objects of labour and energy, information is becoming an organic and specific element of production whose development and use must be taken into account in planning and management.

Let us note that between information and production, or service there is a definitely oriented energy by means of which is performed the action which becomes necessary in connection with the given information. This is exemplified by the electronic computer, which transforms information into a programme, and the programme—through a system of devices issuing command impulses—into energy, and the energy into some action of the executing mechanism. Information is effected only through the actuation of this servomechanism.

In this sphere as well, specialisation and separation come to be the key conditions for the formation of structural elements. While energy, and the objects and instruments of labour are the basic conditions for effecting the process of production, information turns out to be the most active, organising element, the instrument by means of which production is set in motion and directed.

Research facilities are another non-traditional element of the means of production, and they tend to become ever more diverse and complex. Their unit capacity and their saturation of scientific establishments in the USSR and other developed countries have been steadily growing. At the beginning of the Tenth Five-Year period, fixed assets in science and scientific establishments were valued at roughly 20 billion rubles. Particle accelerators, experimental devices, electron microscopes, the facilities in space research, electronic computers, and various other devices have been rapidly growing and developing. Many types of these facilities are used in the laboratories of big plants, while many experimental installations tend to become, with the advance of science, prototypes of experimental and production equipment to be used for the industrial realisation of various tech-

nical projects.[1] But it would hardly be right to include research facilities among the means of labour in material production, unless, of course, we include science in material production. All these considerations suggest that these facilities should be regarded as an independent functional element of social production.

Let us consider in greater detail the development of these elements under the impact of the STR.

Below I deal to some extent with the prospects both of scientific and technical progress and the development of the basic elements of material production in the USSR in the 1980s and 1990s.

2. THE ENERGY BASE OF PRODUCTION

The scale, structure and trends in society's changing requirements in energy largely reflect the lines on which the technical re-equipment of production has developed. One of the most important trends in the present-day and foreseeable development of material production, and the non-production sphere of the services is their steadily growing energy-intensiveness and especially their electricity-intensiveness. This trend is quite natural and is a reflection of the *special role energy has to play in economic development and human life.*

On the energy available per person in production, the non-production sphere and in everyday life largely depends the development of social production, the extent to which man masters the forces and resources of nature, the level of labour productivity in any sphere of human activity, the level of mechanisation and automation, changes in working conditions, the development of culture and accessibility of all its values, and the creation of the utmost possible comforts for human beings.

Technical progress at its present stage is characterised by the extensive and ever growing introduction of electrotechnological processes, and the emergence of lines of production based entirely on the use of electric technology.

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[1] Let us consider, for instance, that the first thermonuclear energy for peaceful purposes will be generated by something like the Tokamak or another experimental installation.

One need merely point to electrometallurgy, electrochemical lines of production, electrotechnological, electron-beam and electrochemical processes in engineering, the atomic, pulp-and-paper and cement industries, the making of artificial ice and the refrigeration industry in general, etc.

Mechanisation and automation are also expressed in the continued saturation of production by diverse mechanical and other devices set in motion by electric power.

High-temperature processes are being increasingly used in modern production; the thermoproduction is becoming an ever bigger consumer of primary energy-carriers. In some industries, the thermoconsumption is much greater in volume than the consumption of power, mainly electric, energy.

Thus, in 1970 (by the end of the Eighth Five-Year period) the generation of electric power in the USSR came to 740.9 billion kwh, and the production of thermal energy by centralised sources, to 1,296 million gigacalories, or in electrical equivalents[1] 1,507 billion kwh. The proportion was roughly similar in the Ninth Five-Year period.

These data show that while electric power has an exceptionally important and leading role to play in the overall energy balance in the modern world, the development of energetics should be seen in a much broader context, taking into account all the consumption of energy in all its forms and also the relative efficiency in the use of electric and other types of energy in every sphere in which they are applied. That is the only approach which could help to obtain a correct solution for the problems arising in the development of energetics today and in the future.

The steady growth of the volume of operations involving the transportation and movement of objects and products of labour and of human beings has led to the emergence of a major consumer of energy, namely, every type of transport facility, including road, rail, air and water.

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[1] 1 kwh = 860 kilocalories; 1,000 kwh = 860 gigacalories.

Energy is also highly important in the protection of the environment.

The growth of living standards in the present-day conditions is also expressed in the most extensive equipment of diverse institutions in the everyday and cultural services and households with various devices and appliances operating on electric power.

> US data give an idea of the scale of electric-power consumption by urban and rural inhabitants for household needs. In 1971, the United States had a population of 207 million, and they used 482 billion kwh of electric power, i.e., 2,330 kwh per head.[1] In the USSR, the figure is lower for the time being, but it is bound to grow and will exceed it in the foreseeable future.

All of this determines the *steady growth in the consumption of energy both in production and in the non-production spheres.* Over the past century, the consumption of energy multiplied 20-fold, while the population of the globe only doubled. The generation and consumption of electric power grew even faster: in the 26 years from 1951 to 1976, world consumption of basic energy resources (in terms of conventional fuel) increased three-fold (from 2.85 billion tons to 9.06 billion), while the generation of electric power multiplied sevenfold, from 989 billion kwh to 6,933 billion kwh.

Quite naturally, over the whole of the past century there has been a steady and, one could say, *unremitting growth in the production of the basic energy-carriers* all over the world. This will be seen from the following data.

World output of the basic energy resources—coal, oil, gas and hydropower—expressed in their electrical equivalents, was as follows: 1860—1.1 trillion kwh, 1900—6.1 trillion kwh, 1940—15.9 trillion kwh, and 1959—32.4 trillion kwh. According to our estimates, in 1970 it came to 60.4 trillion kwh and in 1974 to 69.1 trillion. It is noteworthy that over the past 20 years the pace has accelerated.

In 1976, mineral fuel (coal, oil and gas) accounted for 89.6 per cent of the world's consumption of energy resources, with oil and natural gas rising to the top of the list

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[1] See *Electrical World*, Vol. 176, No. 5, 1971; *The Handbook of Basic Economic Statistics*, October 1974, Vol. XXVIII, No. 10, p. 12.

(61.5 per cent). While the share of hydroenergy resources has been growing, it still accounts for only 6.6 per cent, and bears no comparison with any of the mineral fuels.

The share of hydroelectric power stations in the production of electric power is larger than the share of hydroenergy resources in the overall consumption of energy, but they, too, are not at the top of the list. In the USSR, hydroelectric power plants accounted for 14 per cent of total energy generation in 1950, 17.4 per cent in 1960, 16.8 per cent in 1970, and 12.2 per cent in 1976.

In 1970, atomic power accounted for a very small share of the total electric power generated. In the USSR, it came to 0.5 per cent (3.5 billion kwh), and in 1979 to 4 per cent (50 billion kwh) with more than 14-fold increase.

The share of atomic power stations is also highly insignificant in the electric power industry in the capitalist countries, with the exception of Britain, where it came to 7.4 per cent in terms of capacity, and to 11.1 per cent in terms of power generation. Below are the 1977 data on the installed capacity of atomic power stations and the generation of electric power.[1]

	Installed capacity (thou kw)	Generation (mln. kwh)	Per cent of all installed capacity	Per cent of all power generation
Britain	5,890	40,021	8.1	14.1
USA	49,882	250,883	8.7	11.3
FRG	6,271	36,059	7.9	10.8
France	4,599	17,986	8.8	8.5
Japan	8,007	31,659	6.5	5.9

In the first half of the 1970s, therefore, energetics, notably, electric-power generation, was based on quite traditional energy-carriers, with atomic energy still accounting for a very small share. Just as traditional throughout the world is, for the time being, the process of conversion of fuel into mechanical energy and the transformation of the latter into electricity with a low efficiency. The revolution in energetics

[1] See *1978 Statistical Yearbook of the United Nations*, pp. 395, 397, 401, 402, 405, 407, 411, 412.

in terms of the industrial generation of energy has obviously still to occur. Indeed, just now it seems to be a thing of the future.

Before describing the STR in energetics, one has to analyse more circumstantially the *trends in the changing pace and structure of energetics itself in the second half of the current century.*

The production and consumption of energy have grown at a high rate, and its production has grown much faster than the whole of social production. From 1951 to 1960, for every 1 percentage point of national-income growth the generation of electric power came to 1.2 per cent; from 1961 to 1970, to 1.27 per cent, and from 1971 to 1977, to 1.16 per cent.

The Soviet Union, narrowing the gap between it and the United States, rose to second place in the world in the consumption of energy and the production of electric power. In 1950, the USSR's generation of electric power came to 22 per cent of the US figure, and in 1977, to 49 per cent, thus more than halving the gap. In 1977, the USSR's industrial consumption of electric power came to 80 per cent of the US level.

Over these 20 years, an *ever growing share of fuel and energy resources has gone into the production of electric power and thermal energy*: 26.4 per cent in 1950, 32.6 per cent in 1960, 40.9 per cent in 1970[1], and 43 per cent in 1976. That is their most efficient use, and it has helped to keep the growth of the total consumption of energy below that of the national income, despite the fact that the national income is increasingly energy-intensive and electricity-intensive.

For every 1 percentage point of national-income growth it was necessary to increase the consumption of fuel and energy resources as follows: from 1951 to 1960, by 0.72 per cent; from 1961 to 1970, by 0.73 per cent, and from 1971 to 1976, by 0.84 per cent.

Reported and forecast data clearly indicate a trend towards more extensive and profound electrification of production and everyday life. Considering that in 1977 the USSR generated 4,442 kwh of electric power per head, as compared with 10,609 kwh for the United States, it will be obvious

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[1] Including the cost of compressed-air production.

that the high rate of electric-energy growth needs to be maintained over the foreseeable future.

Published data give an idea of the possible scale on which the consumption of energy could grow.

> From 1950 to 1977, the USSR's national income increased 7.7-fold (from 1950 to 1976—7.23-fold), while energy consumption went up from 331 million tons of conventional fuel to 1,481 million tons (from 1951 to 1976), i.e., 4.5-fold, and the production of electric energy, 12.6-fold. Industrial output increased 10.9-fold, while industrial consumption of electric energy went up 11-fold. From 1970 to 1976, agricultural output increased by 7.2 per cent and the consumption of electric power by 140 per cent. Freight turnover increased 7.6-fold and its consumption of electric energy, 22.4-fold.

The energy-intensiveness, including the electricity-intensiveness of material production as a whole (in terms of the national income) and its various sectors will evidently remain at a very high level in the foreseeable future. The STR, while creating the conditions for keeping the economy supplied with growing energy resources, also tends to increase the energy-intensiveness and the electricity-intensiveness in social production, i.e., to stimulate society's requirements in energy, electric power in the first place.

The non-production sphere is becoming rapidly growing consumer of energy and electric power. This includes housing and public utilities, the retail trade, public catering and other sectors of everyday services, education, culture, public health, physical culture and sports, etc. In the second half of the 1970s, as in the 1980s and the subsequent period, there will be intensive technical re-equipment of these sectors, and this will sharply increase their requirements in energy, especially electric power.

> At the end of the 1990s, the USSR, with a population of over 300 million, will reach the rate of electric-power consumption the United States now has (2,200 kwh per head a year), and this means a total annual volume of everyday consumption of electric power coming to 660 billion kwh, and with the attainment of the overall

per-head consumption of even 5,000 kwh, that is, less than the United States plans to have, considering its advertising excesses, 1.5 trillion kwh.

The high level of electrification in everyday life is evidently the basic element in the people's rising material and cultural standards, and a necessary feature of the material and technical basis of communism. The above figures are no more than prognostications, but they testify to the highly impressive scale on which energy resources will be required in the process of the USSR's subsequent economic development.

The five-year plan for the USSR's economic development from 1976 to 1980 set the target of increasing electric-power output to 1,380 billion kwh by 1980, or by 33 per cent, with the national income growing by 26 per cent. This means that in the Tenth Five-Year period, the generation of electric power still have a priority rate of growth.

It should be noted that the structure of energy consumption in the recent period and in the foreseeable future tends to change towards an increase in the share of forms which themselves require growing quantities of primary energy for their production and transmission.

This is exemplified by the generation of electric power itself, for it entails a loss of nearly 75 per cent of the energy contained in primary energy-carriers. This puts an added value on efficiency under which primary ("raw") energy can be converted into useful work. Considerable advances have been made in this field over the past several decades.

In the USSR, the quantity of conventional fuel required to generate 1 kwh of electric power at electric plants in general use was reduced from 645 grams in 1940 to 377 grams in 1976, and this saved 60 million tons of fuel over a period of five years. From 1940 to 1976, the expenditure of fuel per gigacalory of thermal energy produced fell from 207.7 kilograms to 173.4 kilograms, or by 17 per cent.

However, specialists estimate that within the framework of the existing technology of energy production the possibilities for reducing losses and per-unit inputs of primary energy-carriers are relatively limited, because the technical basis of present-day energetics rests on highly uneconomical principles. There are large losses at every stage in the production and consumption of energy. Contemporary energy units

are highly uneconomical. A turbine-and-generator block is a complex and costly machine based on the transformation of thermal energy into mechanical energy, and of mechanical energy into electric power. It contains rotating parts which are in friction with each other, to overcome which a large part of the energy is spent. There are also considerable losses in the transmission of electric power, and also in the energy-consuming units and instruments. As a result, a large part of the energy contained in the primary energy-carriers is lost, and this is a part which has the largest specific weight.

Thus, a UN calculation[1] shows that only just over one-third (35 per cent) of all the primary energy in the world's production of fuel and energy (a calculation for 1952) was converted into useful energy, with nearly two-thirds consisting of various types of losses.

The design of present-day internal combustion engines is also based on the principle of conversion of thermal energy into mechanical energy with rotating parts, and this also makes for very low efficiency.

> Thus, it comes to about 30 per cent for ordinary automobile internal combustion engines, which means that of every 100 litres of petrol burned up in the car almost 70 litres goes up in smoke. Even the most economical engines used in modern diesel locomotives, ships and planes use up something like 75 per cent of the fuel without any returns.

But while the losses of energy in the process of its production may be vast, there is also the problem that the energy units, even the most modern and perfect ones, are much too cumbersome and far from always reliable.

Nor is that all. One of the key causes of the low efficiency of thermal electric-power stations is the temperature limits of available structural materials.

Considerable effect is produced by the enlargement of the unit capacity of energy assemblies, but even this has its reverse side. Designers are already concerned over the strength

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[1] *Peaceful Use of Atomic Energy*, United Nations, Vol. 1; *The World's Requirements for Energy. The Role of Nuclear Energy*, United Nations, No. 1, 1956, p. 5.

of structural materials, the reliability of electrical insulation and the vibration strength of the giant machines. Many difficulties also arise in servicing the lines and equipment of powerful substations.

Such are the starting conditions and objective trends which constitute the background for the STR in energetics.

A key feature characterising the energetics of the now shaping stage in the development of large-scale machine production is the growing energy-intensiveness of material production, the services and everyday life.

The second essential feature of this stage is the growing specific weight of electric power in the overall production and consumption of energy, including an ever greater share of electric energy in the production of heat.

When assessing the prospects before power engineering itself, one should bear in mind that the production of heat—technological and everyday, and in the recent period increasingly the production of cold—for the time being remains the most important item in the overall expenditure of energy resources. As technology develops, there is a steady growth in the heat-intensiveness and "cold-intensiveness" of social production. At the same time, scientific and technical progress creates the potentialities for installing ever more efficient and economical technology for the production of electric energy. In these parallel processes, with the existing trends in their development, a critical point is reached at which electricity could provide the most efficient and economical mode for obtaining heat and cold. This critical point has already been reached in some industries and lines of production (electrometallurgy, electrochemistry and electrothermic processes).

With the onset of such a situation, the consumption and accordingly the production of electric energy is bound tremendously to increase. The last two decades of this century and the beginning of the next could be marked by a switch to electric heat. Of course, atomic energy could appear on the "market" as an efficient and powerful rival of electric energy in the production of heat, but one could hazard the assumption that it will be thermonuclear energy, an even stronger rival, because atomic energetics gives rise to problems of radiation resistance.

In 1973, Japan's Ministry of International Trade and Industry decided to start a programme to build up a metal-

lurgical complex operating on nuclear fuel. It provides for the development of a multipurpose, highly powerful gas-cooled nuclear reactor. The complex will not have any open-hearth or blast furnaces, nor will it be in need of oil or coal, but will produce pig iron and steel by means of an extremely hot recovery gas generated by the heat of the powerful nuclear reactor.

These characteristics which predetermine a continued and considerable growth in the volume of energy production, especially of electric power, naturally bring out as the *key problem the selection and use of the most efficient and economical primary energy-carriers.*

There is every indication that over the next decade energetics, both in the USSR and the United States, will be based on a combination of mineral and atomic fuel with a prevalence of the former. Accordingly, the potentialities of the STR will be applied in atomic and nuclear energetics, and in the use of mineral fuel. Our assumption is that until the end of this century thermonuclear power engineering will not be at all prominent in the world production of electric power, even if its technical problems are solved in the 1980s or 1990s. That is the view taken by physicists in all the developed countries, who assume that thermonuclear energetics will come to the fore in the first half of the 21st century.

The Soviet Union has adequate quantities of traditional energy resources to ensure its growing requirements for decades. But another problem is acute. In view of the vast requirements in energy and their steady growth, exceptional importance attaches to the problem of meeting these requirements by providing the most efficient and economical energy, and that is where the STR with its potentialities becomes relevant.

We have the mineral and the hydroenergy resources, but a number of technological and technico-economic problems tends to arise when one considers the quality of the various types of fuel and also the conditions and the costs of transporting and transmitting the energy.

It does not pay to transport low-calory fuel over great distances. The transportation of any, even the best, types of fuel requires the construction of railways and pipelines. Its transmission in the form of electricity generated by electric-power stations requires gigantic and very costly transmission lines. Meanwhile, the construction of energy-intensive

enterprises in areas where the sources of energy are located entails a complex of other factors: settlement of the population, the extent to which the area is habitable and already settled, the location of the users, and so on. One example will suffice. On the spot, coal in Ekibastuz and gas in Bukhara cost 2-3 rubles in terms of a ton of conventional fuel, but once they are delivered to the European part of the USSR, the cost of the gas goes up to 10 rubles, and of the coal to 12-14 rubles.

Economic analysis shows that it is worthwhile to build large-scale thermal electric-power stations operating on coal mined in the Ekibastuz and the Kansk-Achinsk fields, and this has been written into the Guidelines for the Development of the National Economy of the USSR for 1976-1980.

At the same time, there is the problem of developing atomic energetics. There is no need here to argue the merits of nuclear fission.

> Let us recall that a kilogram of nuclear fuel is equivalent to over 2,000 tons of coal. Prepared and used in the form of rods with heat-generating elements, it can be stored in very small storage rooms. An atomic-power station uses up only about 30 tons of slightly dressed uranium in one year of uninterrupted operation, as compared with about 2.5 million tons of hard coal for a thermal station of similar capacity.

The problem of transporting primary energy-carriers is, evidently, a problem that atomic energetics does not have to face. The elimination of the need to locate atomic-power stations close to the sources of energy-carriers largely eliminates the problem of transmitting electric and thermal energy, because atomic-power stations can be built in areas of its mass consumption, i.e., with an eye to the requirements in energy instead of the possibilities of providing energy-carriers.

The development of atomic-powered engines opens up tremendous potentialities. Ocean vessels propelled by atomic energy are autonomous and independent on voyages ranging over tens of thousands of miles.

The 25th Congress of the CPSU was told by P. S. Neporozhny, USSR Minister of Power Engineering and Electric

Power Stations, that in the Tenth Five-Year period, at least 70 million kw of new energy facilities are to be started, with at least 15 million kw (i.e., over 20 per cent) in the form of atomic-power stations. A start is to be made on the building of large-scale atomic-power stations with an installed capacity of 4-8 million kw with thermal neutron reactors of 1 million, 1.5 million, and 2.4 million kw.

At the same time, one should also take into account that some leading physicists have made serious critical remarks with respect to uranium energetics. Academician Pyotr Kapitsa, one of the most prominent physicists of our day, listed the following complicated problems in this area: great technical difficulties in reliably dumping the radioactive waste of uranium reactors; considerable danger for the environment posed by new atomic-power stations with unit capacities of several million kw; and, finally, a point which is of great international importance, namely, the extensive spread of plutonium, which is a necessary component for effecting a nuclear reaction, and which is also the potential basis of atomic weapons. Academician Kapitsa said that this could result in a situation in which the atomic bomb could be used as an instrument of blackmail by an enterprising group of gangsters.

According to him, in order to overcome these difficulties, electric-power stations could be built on uninhabited islands in the ocean. But the best way out, he continues, is to obtain energy through the thermonuclear synthesis of deuterium and tritium, because the thermonuclear process does not yield tangible quantities of radioactive sludge, it is not dangerous in an accident, and cannot be used as an explosive substance for a bomb, while the stock of deuterium is larger than that of uranium.

Below I shall deal with the possibilities of thermonuclear synthesis, but just now, for all the serious considerations, like those expressed by Academician Kapitsa, there is an intensive buildup of uranium electric energetics all over the world. One need merely cite the table on p. 142. It indicates that as early as in 1977 by atomic power stations (uranium) in the USA was produced 11.3 per cent of all power generated in the country, in Britain—14.1 per cent, in FRG—10.8 per cent.

This rapid development of atomic energetics poses the highly acute task of the economical use of nuclear fuel re-

sources—uranium (and partially thorium), which is highly dispersed in nature and is hard to extract. The content of uranium in ore usually comes to between a few hundredths of a per cent to a few tenths, i.e., from 0.4-0.5 to 1-3 kg per ton of ore. But that is not all. In natural uranium (separated from the ore) it is only its isotope U-235 that is subjected to fission in the nuclear reactor, and the latter's content in natural uranium comes to only 7 kilograms per ton.

Consequently, although it already makes economic sense to build powerful atomic-power stations with thermal neutron reactors, N. M. Sinev, Deputy Chairman of the Committee for the Use of Atomic Energy of the USSR, says that the relatively cheap uranium, whose price makes atomic power stations with thermal neutron reactors economically profitable, is found in limited quantities and is bound to constrain the development of atomic energetics.

The STR provides a solution of this problem as well. With the aid of excess neutrons (those which are not needed for the nuclear-fission reaction) the whole of the thorium and the U-238 could be converted into new artificial elements, plutonium or U-233, which make excellent nuclear fuel. This occurs in special types of reactors, those which operate on fast neutrons.

As a result, the use of enriched U-235 for fission in the atomic zone of a fast reactor can produce 10-15 per cent more plutonium atoms for each of its burnt-up atom, while the use of plutonium could raise the coefficient of reproduction to 1.5, which means that one could obtain 1.5 kilograms of new fuel for each kilogram of fissioned fuel.[1]

That is the answer to the successful development of large-scale atomic energetics.

The development of efficient breeder reactors, and a radical solution of the problem of atomic fuel on that basis is the primary and fundamental problem facing atomic energetics.

Everyone has heard of the Soviet Union's successes in building and operating atomic electric power stations. By the beginning of 1972, construction and assembly work was completed at the world's largest atomic power station with a 350,000 kw fast-neutron reactor at the town of Shevchenko

[1] Plutonium is formed from U-238 nuclei in any reactor operating on "slow" neutrons, but the coefficient of reproduction (conversion) there is less than unit. That is why nuclear fuel can be multiplied only through the use of fast neutrons.

in the Trans-Caspian area. Above there were showed the great successes of Soviet scientists, both theorists and experimenters, in mastering thermonuclear energy.

In the Ninth Five-Year period, a 600,000 kw fast-neutron breeder reactor was started in order to solve the problem of enlarging the fuel resources of atomic energetics. Soviet reactor, the BN-600, has demonstrated yet another tremendously important potentiality of atomic energetics. In the near future, this atomic power station will provide the basis for the operation of six installations for desalting sea water. One such "battery" has already been built and is being used.

Considering that in the foreseeable future, traditional (non-atomic) energetics will continue to dominate the overall generation of electric power, primary importance attaches to two problems whose solution is made possible by the current STR.

The first of these is a *radical improvement in the techniques of obtaining electric power* and raising the still very low efficiency of electricity-generating units.

The second is to *make long-distance electric transmission lines more efficient and economical.*

In the solution of the first problem some effect is derived for thermal power stations by switching to higher steam parameters, and for all types of stations, by increasing unit capacity of individual blocks (boiler—turbine—generator-transformer), and of the station as a whole.

The USSR already operates the world's most powerful—508 Mw—hydroturbines, which are installed at the Krasnoyarsk hydropower plant. Hydroturbines with a capacity of 650 Mw are already being designed and prepared for production for the Sayano-Shushenskoye hydropower plant. Two blocks of 800 Mw each are already in operation at the Slavyanskaya state regional electric power station in the Donbas. Six such giant blocks will be in operation at the Chigirinskaya state regional electric power station. An energy block with a capacity of 1,200 Mw together with a unique steam turbine and a boiler unit with a productivity of 3,950 tons of steam per hour is soon to be completed and delivered to the Kostroma state regional electric power station.

In the Tenth Five-Year period, construction will be continued on thermal power stations with a capacity of

400-600 Mw and energy blocks with a unit capacity of 500-800 Mw.

500-Mw turbines have been installed at the Leningrad atomic electric-power station, while plants in Kharkov and other cities are preparing to turn out 500 Mw and 1,000 Mw units with 1,500 revolutions per minute for atomic power stations.

Let us recall that with an increase in capacity (all other conditions being equal) the blocks tend to be less reliable. That is why the advance to larger blocks must go hand in hand with a qualitative restructuring of every individual element and the development and use of new and better materials.

The most important successes will evidently be connected with the *development and use of a fundamentally new techniques for the generation of electric power.*

Even atomic energetics, the product of the STR, does nothing essentially to modify the traditional techniques for obtaining energy, but merely changes the primary energy-carrier, the type of fuel. The atomic reactor is, in effect, used as a furnace for the same steam boiler, and this is followed by the same multistage cycle in which heat is transformed into mechanical energy, and mechanical energy is transformed into electric power by means of the generator.

MHD — magnetohydrodynamic generators — are a fundamentally new method for obtaining electric power which make it possible markedly to increase efficiency.

The technological description apart, let us note that the fundamentally new thing about MHD generators (if the method is mastered) is that they allow to convert heat directly into electricity without boilers, turbines, armature or any moving mechanical part. This revolutionary change and the reduction in the cycle of electric-power generation could help to increase the efficiency to something like 50-60 per cent, which is much more than can be attained at the best thermal power plants.

A model installation of a commercial thermal plant with an MHD generator feeding current into the Mosenergo system has been in operation in Moscow since 1965. Of course, many complicated technical and economic problems, notably that of reliability, still have to be solved in the development and use of MHD generators.

The *use of heat from the bowels of the Earth for the needs of energetics on a substantial scale is in a similar state.*

The bowels of the Earth contain vast resources, of which 38,000 billion tons of conventional fuel rise to the surface every year: 90 per cent because of the heat-conductivity of rock, and 10, through convection via volcanoes, fumaroles and geysers. At a depth of 10-15 kilometres, the temperatures come to several hundreds of degrees, which is, in principle, enough to obtain steam and to generate energy with a good efficiency. However, Academician Kapitsa notes, the heat conductivity of rock is low and with the small temperature gradients down there the heat will have to be conducted from over very large areas to obtain the quantities necessary to heat water, and this is very difficult to do at such depths.

At the present time, the capacity of all the thermal electric power stations (TEPS) operating on geothermal sources all over the world totals over 1.5 million kw. It is estimated that within 10-20 years, such power plants will account for 1.5 per cent of the capacity of all the power plants in the world, a fairly large magnitude, considering that hydropower plants now account for only 3 per cent of the electric power generated in the world. The USSR has the Pauzhetskaya TEPS in Kamchatka, and it generates electricity which is over 30 per cent cheaper than that produced by other power plants in the area.

Nevertheless, geothermal energetics is still in its early childhood, according to scientists of the G. M. Krzhizhanovsky Energy Research Institute. All the geothermal plants now in operation have been built on sources lying at relatively small depths and with steam or water temperatures above 170 ° C. But this question arises: is it possible to build a geothermal plant where there are consumers of energy and heat? To solve this problem it will be necessary to extract the heat accumulated in hot rock.

Commercial use of geothermal energy will be arranged above all in areas with a higher temperature gradient, in places where the temperature is 70-100° at a depth of 1.5-2 kilometres. Such areas have been discovered in the USSR in Daghestan, Armenia, the Western Ukraine and in the Stavropol Territory. When drilling to a depth of 8-9 kilometres becomes economical, it will be possible to erect geothermal plants in any geographical area, wherever the need arises.

There are a number of technical difficulties in the commercial development and spread of this type of energetics, which is why it is still too early to consider when the mass use of such energy will make technical and economic sense. Still, mankind is already trying to master this source as well.

The use of *solar energy* is a prospect that is of considerable importance, for this type of energy has its own fundamental distinction and various advantages.

Not only atomic energy, but also thermonuclear energy (which from the standpoint of radioactivity is regarded as "clean") are not "pure" enough, because they produce "thermal pollution" of the globe's biosphere. Doctor of Technical Sciences B. V. Tarnizhevski, sector head at the Heliotechnical Laboratory of the Krzhizhanovsky Energy Research Institute, says that all the types of energy obtained artificially are supplementary to the solar radiation which reaches the Earth, and because of this, production of energy on a scale which comes to only a few per cent of the solar heat received by the globe could lead to a global warming up and irreversible changes of the biosphere, including the climate. But there is no need to fear this, he goes on, if solar rays are used as "fuel".

The low density of solar radiation—Academician Kapitsa puts it at 100 watts per square metre of sun-lit surface—is the greatest problem in the use of the Sun in large-scale energetics. But there are hundreds of thousands of consumers for whom solar energy can already become the only economically justified type of energy supply. Only in agriculture, there are over 300,000 such consumers.

Soviet scientists and designers have developed a number of solar installations for various purposes which are capable of winning the economic competition against those operating on mineral fuels. They are being successfully used for drying some produce, growing vegetables in helio-greenhouses, and drawing water. The Sun already supplies hot water to the Sportivnaya Hotel in Simferopol. In Ashkhabad, construction work is under way on three experimental houses where air-conditioners will be run on solar radiation. Experimental installations helping to satisfy everyday needs are already available. The use of this source for large-capacity energetics is a much more difficult problem.

Bearing in mind Academician Kapitsa's figures given above, one will realise that in order to generate 100 Mw, it will be necessary to collect energy from an area of 1 square kilometre, which hardly makes economic sense.

In the Tenth Five-Year Plan (1976-1980), more than a dozen experimental buildings with solar-heating systems were built in the USSR.

In principle, the "energy field" which in the Karakum Desert occupies an area of 70 by 70 kilometres, could be paved with solar batteries to obtain over 1 trillion kwh of electric power, that is, as much as all the electric power stations of the Soviet Union generated in 1976 and 1977.

However, for the time being the cost of solar batteries is too high, and it needs to be reduced to a few per cent of the present figure. There are various versions for technical solutions of this problem which are to be tested so as to accelerate the inclusion of solar energy into the Soviet Union's grid.

People once again turn to the use of *wind power* on a new technical basis. According to some estimates, by the year 2000 the United States will be able to supply up to 20 per cent of its electricity consumers through the use of wind power. Japan, Denmark, France and other countries have state programmes for using wind energy.

I. A. Babintsev, Director-General of the All-Union Research Association known as Tsiklon, has estimated that over the next few years the USSR could start 150,000-200,000 wind units with a capacity from 1 kw to 30 kw. The task is to produce "energy hybrids" of wind and thermal power stations. Wind power could be used to generate electricity at the thermal plants when it reaches the necessary level, so saving up to 60 per cent of the mineral fuel.

Wind energetics has great potentialities in the polar regions. Thus, in the area of Cape Shelag, Pevek district in the Chukotka Peninsula, where the "working wind" blows an average of 6,500 hours a year, a wind-driven electric-power plant could generate 660 million kwh of electric power a year at very low cost.

One idea is to erect a "wind dam" to serve as a barrier to the hot dry wind which regularly hits the Fergana Valley. A system of wind units intercepting the hot dry wind before it reaches the valley, could "transform" it into electric power and then transmit it on in that tamed form. Babintsev has estimated that by the year 2000, the USSR could be generating 460-920 million kwh of electric power a year through the use of wind energy.

There is some experience in the use of the energy of *marine tides.*

> The USSR's first tidal power plant at Kislaya Guba, North of Murmansk, on the coast of the Barents Sea, was started back in 1969. Its operation has been stable and it has generated electricity not only during ebbs and flows, but also at peak hours, regardless of how the tide runs. Its experience has made it possible to start on the design of more powerful plants of this type. The first of these, the Mezenskaya tidal power plant, with a capacity of 1.5 million kw, generates 6 billion kwh a year. In future, it will be possible to obtain a powerful flow of electric energy on the coast of the White Sea estimated at 36 billion kwh a year.

Such in general terms are the potentialities of the STR in the quest for new and more progressive energy-carriers and the use of new technological principles for generating electric power.

Super-conductivity is another STR achievement which is of primary importance in improving energetics.

Conductors are used to transmit electric power. Conventional conductors have resistance to electricity and for that reason tend to heat up when current passes through them. This means considerable losses and, naturally, a reduction in relative efficiency. Besides, there is a need to dissipate the heat, as otherwise the conductors may overheat and even melt. Conductors are a necessary part of many electric-power units.

Super-conductivity has prompted to develop and use light and very powerful super-conducting electromagnets, which are highly important in various types of hardware. In particular, they help to make generators, transformers and engines much more economical, and also markedly to reduce their size, weight and cost.

A solution of the problem of super-conductivity at optimally high temperatures (i.e., the temperatures of liquid air, and ideally, at normal room temperature) would result in a tremendous increase in the efficiency of electric energetics and power engineering generally.

The successes of high-pressure physics hold out much promise in this field, where Soviet scientists have made major advances. The industrial production of artificial diamonds has long since been developed under the direction of Academician L. F. Vereshchagin at the Institute of High Pressures of the USSR Academy of Sciences. Over the past few years, the institute has been working to obtain metallic hydrogen.

The transition of dielectric hydrogen into metal hydrogen, says Academician Vereshchagin,[1] is a more exciting problem than the transition of natural diamond into a metallic state, because in the former instance we obtain a unique superconductor with a very high critical temperature, from 200° to 300° K, which is close to room temperature. That is the most important aspect of super-conductivity on which its successful industrial application largely depends.

As in some other fields, a number of other highly important potentialities appear at the conjunction of new scientific and technological solutions. This hydrogen, Academician Vereshchagin says, "could become the ideal type of fuel both in terms of the quantity of energy contained in 1 cub. cm, and of the absolute absence of waste". There is also the fact that metallic hydrogen is a "durable material, much more durable than all the other metals of the periodic system."

Let us note that the raw material resources for the production of hydrogen are virtually unlimited.

Thus, the face of energetics over the past third of the 20th century, the stage of "pre-thermonuclear" energetics, is made up of super-powerful thermal hydraulic and gas turbines with the use of super-conductivity, fast-neutron atomic energetics; MHD generators, fuel elements, and long-distance electric transmission lines with the use of super-conductivity.

Automobile engines consuming a tremendous share of the world's energy resources and the chief factor in air pollution are an important and growing factor in contemporary society.

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[1] See *Priroda*, No. 4, 1976.

Hundreds of millions of cars clog the streets of cities, and the roads of all countries and continents. Smog and the noise of millions of engines erode, like malignant diseases, the organism of large cities and do irreparable harm to the health of millions of people. A vast tanker fleet is employed in transporting liquid fuel, ever more frequently contaminating the waters of the World Ocean. A sprawling oil-refining industry is engaged in turning hundreds of millions of tons of oil into petrol.

A switch to *electric traction* provides a radical solution to this problem. Small electrically-driven cars capable of making 50-60 kilometre runs are becoming ever more popular in some countries. There is a marked advance in introducing electromobiles in the USSR.

Tangible progress will evidently be achieved when electromobiles will be able to run hundreds of kilometres without recharging. Experts have estimated that if the electromobile is to defeat its petrol-driven rival there is a need to develop accumulators with a capacity of 200 WH for 1 kilogram of weight. The traditional lead accumulator produces only 16-20 WH for every kilogram of weight. The most expensive, silver-zink storage batteries offer only 60 WH, but that is less than a third of what is actually necessary. Air-zink batteries and other types of accumulators are still at the laboratory stage.

The switch to electromobiles will help to make large economies in mineral fuel, but will also present a tremendous demand on electric engineering, which will have to provide the energy backup for the fleet of electromobiles. This will also produce the problem of providing alternative use for the gigantic capacities of oil-refining industry now turning out millions of tons of petrol and, accordingly, for the use of hundreds of millions of tons of oil now being used for these purposes.

By changing the energy basis of production and the non-production sphere, the *STR works a substantial change in the structure of primary energy-carriers and in the technology of energy production.*

At the present stage in the development of production, *atomic energy will gradually come to have an important, and in the subsequent period the predominant place among the newly started energy facilities, and will account for a sizable share of the electric power produced (from a quarter to a third).*

Fast-neutron reactors will evidently be ever more important in atomic power engineering.

Although "machine-less" power engineering (MHD generators and fuel elements) has yet to reach the commercial stage, in the period under consideration, the new technology for the production of energy will evidently be developed to account for an ever growing share as the unit capacity of traditional turbo-generators is increased. But it will hardly be prominent in the 1980s. Machines with the use of superconductivity will still be at the research and experimental stage.

Consequently, power engineering today and in the foreseeable future amounts to something more than a single industry, and adds up to a complex and multisectoral system including the extraction and production of energy-carriers, the generation and transmission of energy, the creation of energy-receiving and energy-transforming mechanisms and devices, and energy consumers proper. From this it follows that the problems in energetics must be studied and tackled from the standpoint of the systems approach.

The Soviet Union has the necessary potential for solving these problems and ensuring a high rate and technical level in electrifying the country at the present stage and in the foreseeable future of its development.

3. THE STR AND THE INSTRUMENTS OF LABOUR

The current STR is exerting an ever more revolutionising influence on the instruments of labour, a key element of large-scale machine production which determines its technical level and the nature of human work.

To gain an idea of the main features of the new stage in the development of large-scale machine production means, above all, to characterise the instruments of labour used at that stage and the trends of change in this field.

Let us recall that Marx regarded the means of labour and the instruments of labour, their main component part, as the most active and revolutionary element of the productive forces. For all the revolutionary changes in the development of the other elements of the productive forces, *improvement of the instruments of labour continues to play the chief role in*

the buildup of the material and technical basis of socialism and communism. On their development largely depends the solution of the basic socio-economic problems of mature socialism and communism.

For its part, the development of the instruments of labour, as of the productive forces as a whole, is itself under very strong influence of social, production relations in each social formation.

This determines the approach to a study of the changes occurring in the instruments of labour under the STR. It would be altogether wrong and inadequate to consider only the material and technical changes occurring in the instruments of labour. Nor is it sufficient to consider them only as impersonal means used to produce some final product, the means of production and articles of consumption.

The social orientation of scientific and technical progress as a whole, especially in the field of the instruments of labour (as of techniques, which is closely allied with them) tends increasingly to become the *categorical imperative for the socialist society.* As society creates and develops its instruments of labour, it exerts an influence on the sphere of social relations, either haphazardly (as under capitalism) or in a balanced manner (as under socialism).

Creative work is a key component of human requirements in the socialist society, and even more so in the communist society. There is good reason why the Marxist-Leninist classics insisted that one of the key characteristics of the communist society would be work as a vital necessity.

That depends not only on the development and improvement of the relations of production, the education of man and development of his moral qualities, but above all on the nature of the process of labour itself, on its conditions and technical equipment.

Consequently, in the socialist society, the instruments of labour, technology, are also designed to meet man's requirements in creative and attractive work which is not physically burdensome, and which is, undoubtedly, one of the values shaping the socialist way of life. As man's intellectual and spiritual standards grow, his requirements with respect to the nature and conditions of work are bound steadily to increase.

What are the most important changes in the instruments of labour that are already in evidence and that go to shape

the new phase in the development of machine production, a phase which is adequate to the material and technical basis of socialism at the stage at which a developed socialist society has already been built?

If one were to start with the line of the revolution in the instruments of labour which is of the utmost economic and social importance, a line which directly affects the nature and content of the labour process, automation should be put at the head of the list. There is good reason why many researchers, Soviet and foreign, regard *automation as the chief and crucial feature of the current revolution in science and technology.*

Automation does not in itself alter the impact of the working machine on the object of labour. The automatic device is, strictly speaking, not the working machine itself, so that it does not change its nominal capacity although it does exert a tremendous influence on the level of its use.

Automation is above all the transfer of the functions of controlling working machines (and various other instruments of labour) to an automatic governing device which purposefully acts on working and other mechanisms. This tends to bring about a fundamental change in the nature of the machine system, by incorporating within it a new and additional element.

Because automation is always machine control of machine operations, it is natural that the automation of this or that process necessarily implies the mechanisation of all the elements of that process, including transportation, movement and control operations. Only then can automatic control encompass the whole range of the given production process. In this sense, automation serves as a catalyst for completing the complex mechanisation of production.

If automatic control of machine processes is to be an advance in scientific and technical progress, it must be enriched with many essential elements.

Automation, as something fundamentally new in the nature of the instruments of labour, begins with the emergence of devices for the automatic control of the instruments of labour. But automatic control, which ensures the start, stop and operation of the equipment in accordance with a pre-set programme (work according to a master-form, etc.) does not, to some extent, go beyond the framework of all-round mechanisation. Moreover, even where the automatic devices control

not only the working machines but also the other types of technological equipment, i.e., the treatment of the object of labour, the shaping process, etc., and also the adjustment of the instruments of labour, and the transportation and movement of the objects of labour, technical control of intermediate and finished products, even then all of these extremely important and technically progressive operations fully fit the concept of complex mechanisation.

The automatic control of working machines and tools in accordance with a programme fed into the controlling device has many advantages, but this type of control lacks one highly important property which human control has, namely, the capacity to react to interference and to eleminate departures from the programme which may arise in the operation of the machine (or any other controlled system). But man is limited with respect to the time and space potentialities of his reactions. That is why an increase in the complexity and speed of operations of production units and systems which are controlled otherwise than automatically tends to run into a contradiction with the limits of human reactions.

This contradiction is resolved through the development of control automatic devices, of a much higher class, which operate on the feed-back principle. These devices, whose technical basis is ever more frequently computers, not only control the operation of the system on the basis of a pre-set programme, but constantly keep track of the results of the work, any interference and reactions, and so control the operations of the production system.

Consequently, the qualitative distinctions between automation and mechanisation clearly stand out with the emergence of control based on the *feed-back principle, or the closed-circuit principle*, as it is sometimes called.

The feed-back principle contains potentialities for other aspects of automation leading to the attainment of a higher stage in the development of control processes. Indeed, the main content of the process of control is the collection, processing and provision of information which, at its final stage, is nothing but a solution expressed by means of this or that control impulse. The feed-back principle is based on the same process: first, receipt of the initial information concerning the set goals and parameters of work of the given system; second, receipt of information about the actual

conditions and the results of the work of the system; third, collation of the information obtained with the pre-set programme, and fourth, output of correcting, controlling decisions in the form of impulses.

Consequently, the process of automation turns out to be closely bound up with information, which serves as the object and the product of labour for instruments of labour which come on the scene.

The growing flow of information threatens to overwhelm the people who are incapable of coping with it because they have at their disposal only conventional instruments of office work, like manual and electric calculators, typewriters, etc.

It is quite natural, therefore, that this is the period in which the science of the principles and laws of the functioning of closed systems and the laws of controlling them—cybernetics—emerges and radically develops, together with fundamentally new types of automatic machines, cybernetic machines.

What are the peculiarities and potentialities of these machines? Up to now, automatic machines were developed to transform, treat and process objects of labour, while cybernetic machines are designed for processing information, solving logical tasks and substituting for man in direct control of technological equipment and production processes as a whole, and also in solving complicated production, technical and scientific problems. They enter into the spheres of human activity (planning and management, technical and scientific research, education, etc.) which have up to now not been equipped with machines at all.

Cybernetics and cybernetic machines, making use of the vast flow of information, and modelling the most complicated processes running through the organic and inorganic world, help to discover new uniformities and mechanisms underlying the development of natural phenomena, i.e., accelerate the development of physics, chemistry, biology and other natural sciences. Cybernetic machines help to model various situations and processes, to determine their possible results, to calculate in advance the longest imaginable chains of successive reactions, combinations of technological processes and technological regimes, and to determine the results which could be obtained through their use.

Cybernetic machines are used for solving economic problems and for drafting plans. They help to calculate mathematically, which variants of the plan will be optimal and under what kind of conditions, so producing the best possible results.

That is the aspect of automatic machines which is connected with yet another key feature of the current STR, yet another aspect of automation, namely, the *potentialities for optimising processes of production and their control at every level in accordance with this optimum.* This means, in effect, the emergence of a new and most powerful factor in boosting labour productivity and enhancing the efficiency of production.

The process of control, once empirical and largely based on past experience and intuition, is being transformed into a process involving the operation of the control machine device, which helps to enrich control itself and to align it with the ever more complicated features and tasks of the controlled system. That is a highly important aspect of the automation of production which has still to be more than marginally realised.

The complexity of contemporary material, above all, industrial production, is expressed in the great diversity and multi-variant nature of the components involved: parts of complex workpieces, materials used in making these, machine-tools and other technological mechanisms, tools and equipment in the numerous and diverse technological processes. The goals and the tasks which society sets before production systems at every level tend to become steadily ever more complex. That being so, the problem of optimal selection and optimal use of all the elements of the production process becomes so important that in material terms it very frequently tends to outweigh any possibilities for reducing the labour-intensiveness of production.

With various modifications, this fact applies to all industries but is especially important in closed-process industries where production is continuous (electric power, engineering, metallurgy, chemistry and petrochemistry, the cement industry, some food industries, etc.), and where output is determined by the interaction of a large number of quick-acting variables of which man cannot simultaneously and dynamically keep track, equipped as he is with the conventional means of production control.

The emergence and development of this aspect of automation show very well that it is quite natural for the current STR to unfold in the epoch of socialism, when a powerful socialist community of states exists and develops on a sizable part of the globe.

The planned socialist economy alone makes it possible to apply the principles of optimisation at all the hierarchical levels of the system of social production. Only under socialism can the local criteria of efficiency and local optima of each subsystem of social production be harmonised with the global criteria and conditions of the optimal functioning of the system as a whole.

Under capitalism, with its antagonistic contradictions which spring from private-capitalist property, the haphazard operations of the market, and competition, it is impossible to optimise production on a large scale. What is more, even the optimisation of any actual production process, of some concrete line of production or some group of production lines is frequently nullified by the fluctuations of the capitalist cycle.

The Communist Party, elaborating its economic policy at the present stage of communist construction, has taken the line of developing automation to the utmost, making broad use of cybernetic machines, and improvement of the whole system of the management of social production by using the potentialities of the STR.

Over the Ninth Five-Year period, the output of computers has increased by 330 per cent, and of the instruments and means of automation, by 90 per cent. A new set of electronic computers based on integrated circuits is being batch-produced.

In the course of the Tenth Five-Year period, output of the instruments and means of automation is to go up by 60-70 per cent, and of computers, by 80 per cent. From 1976 to 1978, their output has actually gone up by 34 and 74 per cent respectively.

Alongside the development of the technical facilities for automation, the task has been set "to further advance and improve the efficiency of automated control systems and computer centres, gradually uniting them into a nationwide data-collection and processing system for the purposes of accounting, planning and management. To set up computer centres for collective use."[1]

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[1] *Documents and Resolutions. XXVth Congress of the CPSU*, p. 189.

Consequently, this stage in the development of machine production will be characterised by automated machie-systems with computer-backed centralised programme control based on the potentialities of the STR which are already being translated into practice. Programme control is to be extensively used because it is the most important condition for the flexible use of hardware. Multiple-position and multiple-tool machine-tools with automatic change of tools and systems of machining, assembly and control machines working on programme control generally will be an important feature.

In the 1970s, the use of *robots* for the performance of some of man's functions was started in the USSR and some other countries. They are used above all in conditions where man is unable to work: where the temperatures are either very high or very low, where there is a high level of radioactivity, in the depths of the ocean, etc. They are also necessary to be used for substituting for human beings in arduous and physically intolerable operations. Finally, with the spread and improvement, they could be more extensively used to substitute for men in monotonous operations, which human beings find increasingly unacceptable as their intellectual and spiritual standards rise.

> Corresponding Member of the USSR Academy of Sciences E. Popov told the press that industrial robots developed in the USSR are able to fasten blanks in machine-tools, to remove machined items and to transfer them from the conveyer belt to the stamping press, to control the operation of machine-tools and the press, and to perform a number of other operations.
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> An international exhibition of robots was held in Birmingham, Britain, in the spring of 1974. The bulletin *Industrie et société* reported that over 3,000 robots were already "working" by then in the United States, Norway, Britain, Japan and France.
>
> In future, with the improvement of design, one of the main areas in which robots will apparently be used is assembly operations in manufacturing, which are now the most labour intensive.

The 25th Congress of the CPSU set the task of getting down to the industrial manufacture of programme-control

instruments and devices for automatic manipulators (robots).

Automation and electronic computers. The great discoveries of human genius, especially epoch-making technical inventions, whose beginnings frequently lie in the solution of local problems, subsequently produce a tremendous resonance effect which has a bearing on the most extensive areas of economic and social life. Automation, automatic control and data-processing machines have produced a resonance effect that is unprecedented in scope.

Above I already mentioned the possible labour-saving effect of automation and the complex effect in saving on living and past labour arising from the optimisation of production.

The combination of automatic data-processing and automatic control machines yields even greater economies of the whole of social labour and produces an important social effect (all of whose components can hardly be anticipated). This is not just a multiplication of productivity, but *fresh potentialities for formulating and solving problems which are simply inconceivable with the use of traditional hardware.* The fantastically growing potentialities of electronic computers have the leading role to play, and their development is the quintessence of the current STR.

Below I shall try to describe the existing and foreseeable trends and basic parameters in the development of data processing computers.

Advances in the field of computers have run along several lines: the elements on which their operations are based have been changing, together with the volume and time potentialities: the capacity of the basic devices and their speed, the extension of the range of functions which they can perform, and a radical improvement of their operation potentialities and convenience in use. Despite the relative youth of this hardware (the first computers were developed only a few decades ago), there are now actually four generations of these machines.

Academicain V. M. Glushkov, the well-known cybernetics specialist, dates these generations as follows: until 1955, the pre-history of electronic computers; 1955-1960, the first generation of computers, 1960-1965, the second generation, 1965-1970, the third generation. Consequently, the movement is now towards the fourth generation.

What is the difference between these generations? It

lies above all in the elements on which they are based: in the first generation, these were electron tubes; in the second, semiconductors, like transistors and diodes; in the third, microelectronics with a relatively small degree of integration; and in the fourth, a very much higher degree of integration.

First-generation computers were capable of performing several thousand numerical operations per second. Their memory had a relatively small capacity. The installation of all the trappings of a first-generation computer required a large area, great power installations, cable channels and refrigerating units.

The switch to semiconductor circuits in second-generation computers already helped markedly to reduce the weight, size and energy-consumption of all instruments and made them much more reliable. The best electronic tube runs for no more than 5,000 hours, while a semiconductor is good for 70,000 hours. The speed of second-generation computers came to hundreds of thousands and millions of operations per second, while the record speed attained by third-generation computers comes to tens of millions of operations per second. Let us recall that an experienced operator using a key calculator can at best perform 300,000 operations in a year. Consequently, the computer does in one second a year's work by 100-130 operators and in an hour, a year's work by 360,000-470,000 operators. Its memory capacity comes to 16 million bytes,[1] which is equal to the volume of 16 books of 500 pages each.

Fourth-generation computers are based on integrated circuits in which one square millimetre holds up to 5,000 elements. Let us note, by the way, that this masterpiece is still way behind the world's best computer, the human brain, in which each cubic centimetre contains tens of millions of elements known as neurons.

Experts estimate that when the potentialities of fourth-generation computers are fully realised, they will be able to perform 10^9 operations per second. Magnetic-disc type memory with a capacity of 10^{14}, i.e., 100 trillion

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[1] Byte is the designation of eight binary digits, the data unit within the machine, which consists either of two decimal figures or one alphabetic symbol, a letter from some alphabet.

bytes of information, may be developed. That is equivalent to 100 million books of 500 pages each, i.e., a vast library.

The basic features of subsequent generations of computers can already be discerned. Leading physicists believe that the future, new stage in the development of computers will be based on coherent light emission, i.e., the use of highly concentrated beams.

Lenin and Nobel Prize winner Academician N. Basov, one of the inventors of lasers, and doctor of physico-mathematical sciences O. Krokhin, assess these prospects as follows: "Laser devices will apparently help to create the most high-speed elements for computers performing over one billion operations per second." Such speeds will make correspondingly high demands on computer memory, and here again optics will come to the rescue, helping to accelerate the reading process.

The use of lasers and special light-sensitive structures can help to record a unit of data on a few microns, i.e., to fit up to 100,000 such units into a square millimetre. This means, in practice, that the information contained in the thirty volumes of the Great Soviet Encyclopaedia could be recorded on an area the size of a match-box label. And because the laser beam is capable of skanning the surface at a vast speed, this means that such a memory device can operate at a tremendously high speed.

The gigantic growth—by several orders—of computer effectiveness in the third, fourth and subsequent generations means not just an increase in the quantitative potentialities, but qualitative leaps which will make it possible and will even require the formulation and solution of qualitatively new problems with the use of these computers (if their increased potentialities are to be efficiently used). This calls for a steady increase in their load factor. Problems of a size that would require the operation of such a high-speed machine for a long time are not always available in sufficient quantities. Hence the problem, which is being successfully solved, of running computers in parallel.

First and second-generation computers were able to operate only consecutively, which is why they were able to tackle only one task at a time. Third-generation computers are capable of simultaneously working on many problems as

their devices operate in parallel: transcription of information for a problem from magnetic tapes; output of information for some device; input of information; communicating with remote clients via consoles, etc. A special "operational system" to regulate and control the whole range of work is being developed for this purpose.

An important achievement of third-generation computers is the capacity to engage in time-sharing, in which the computer appears to do several jobs simultaneously; actually it works on each job for only a short time before moving on to another.

Fourth-generation computers engage in a dialogue by means of a display-printer device which shows the client what he receives and what the computer sends out. A special light stick is used to introduce information (texts, formulas, charts, drawings, etc.).

The dialogue regime will convert the computer into a direct aid of the specialist, so vastly multiplying his potentialities. The input and output of information by voice is about to be practically used.

In fourth-generation computers (and partially already in third-generation computers) there will be a coalescence of computers and computer centres with a system of communications offering users in various parts of the country services not only in transmitting information, but also in processing it.

The USSR and some other countries plan to set up national "data banks", i.e., a system of computing centres to store data and a system of consoles through which clients will be connected along communication lines with these centres. These data banks will be used by research, design and academic organisations, production complexes, planning and accounting bodies, distribution and supply agencies, etc. All of this will help to make vast economies in social labour.

We are, consequently, witnessing a *real revolutionary offensive by computers as they enter into every sphere of human life.* Automatic control machines are being provided with unprecedented facilities. *Automatic control is becoming the most efficient instrument for saving living and embodied labour.* Science, technology and production are being equipped with ever more powerful instruments for their accelerated development.

Automation produces problems. If the potentialities in the use of the latest technical facilities, like electronic computers, are to be realised, there is a need to solve a number of scientific, technical, technico-economic and organisational problems.

Automatic control machines are now capable of functioning efficiently, i.e., of effecting automatic control of various processes and systems only if they are fed with the necessary programmes and if all the data required for solving these problems are translated into the language of the automatic machines. This means, first, that there is a need to provide functional, mathematical description of the given process, formulated as coupling equations which reflect the quantitative relations of the results of the process and the dynamic of each ingredient, or of the state and dynamic of some external factors.

The complexity of modern production processes and the great number and complex interaction of variables with each other make the formulation of coupling equations a very difficult problem.

The second (and equally difficult) task is precisely to establish the quantitative equations and formulas of the necessary results of the process—of its technical and economic efficiency—which means the data that have to be fed into the machine's comparator. Such data are necessary for comparison with the information being received in the course of the production process. This range of problems has been studied even less adequately. The problem of what the optimal technical and economic characteristics of the results of the given production process have to be is still a long way from solution. In actual production such characteristics are, as a rule, based on experience, and the skills and intuition of the people who run it.

Finally, one very complicated problem is to define the so-called control algorithm, i.e., the set of equations which make it possible to determine in a closed form the extreme (i.e., the extreme and most favourable of all possible) indicators of technical and economic efficiency compatible with the coupling equations and the technical specifications.

The next fundamental and difficult problem is to develop computers specially designed to control production processes. These need above all to have super-reliability, extra-small size and very high speed. This depends on the elabora-

tion of the theoretical principles and the development of the technical facilities for automatic control of production to obtain exhaustive information about the dynamic of the relevant processes and about the quality of the final product.

The solution of all these problems requires much joint effort by industrial engineers and economists, mathematicians and computer specialists.

New and highly exacting demands are being made on the theory of machines, their good grounding and precision. After all, the machine is to operate without man, which means either ruling out any surprises or the need to know about them in advance and so to feed in a programme that would respond to these surprises and help to achieve the required results.

The automatic operation of the instruments of labour makes extremely exacting demands on all the characteristics and parameters of the objects of labour and on their stability. It goes without saying, that an automatic cycle of works implies absolute stability and balance in the operation of all the elements of the organisation of production.

Automation, which springs from the progress of science, also makes new and ever more complex demands on science. There is a need to elaborate a theory and methods for selecting the optimal strategy of automatic control with the availability of incomplete, *a priori* information about the controlled object and any interference in the process of measurement and control. There is a need to elaborate the theory and principles of constructing self-adjusting and other automatic systems capable of adapting to the changing conditions. All these projects—past, present and future—tell the story of how science assumes the responsibility for machines and material production.

Consequently, *automation is a "trouble-maker", a catalyst in the formulation and solution of a whole complex of problems.*

Alongside the range of highly intricate problems described above, there is a second complex of equally complicated tasks in the transition to automation. It consists in the need to assure, when automating various concrete production processes, economies in labour, as compared with the inputs of labour when the work is done by means of hand-controlled mechanisms.

Among these processes are, for instance, assembly operations in engineering, the fitting and honing of units and

parts, the exceptionally labour-intensive operations in the stripping and finishing of rolled stock in ferrous metallurgy (these involve more labour than blast-furnace and open-hearth production taken together), the working of some units and parts making up some piece products, and also unique and many non-standard items, some operations in technical control, servicing of equipment, etc. The list of such operations could well be extended many times over.

In technical terms, some of these operations can already be performed by means of automatic equipment, but these automatic devices are still so complicated and costly that the aggregate labour inputs would increase and this kind of automation would increase production costs as compared with non-automatic methods. Automation of this kind, with the exception of operations dictated by considerations of human safety, clearly does not make economic sense.

Finally, in some industries automation is hard to apply because of the individual character of the final product (fabrication of items to orders, etc.), small scale of production, much too large production areas (this mostly applies to many extracting industries, agriculture, many building operations, etc.).

Some of these constraints can be overcome in the long term by making production more mass in character (in particular, through unification of units and parts), a radical re-thinking of the design of items and the techniques of their manufacture[1] and also through changes in the flexibility and potentialities of automatic devices so that they could be efficiently applied where this is not advisable for the time being.

Solution of the problems of complex mechanisation and then—and on that basis—of automation entails the development of powerful specialised engineering industries turning out transport and moving mechanisms and devices, tech-

[1] This implies a *functional approach* to design, when the task is not to improve the existing design or techniques, but to find a fundamentally new approach to the design of the article, while preserving its function. This is exemplified by the search for ways to improve radio circuits not for the purpose of improving the electronic tubes used in them but to find a fundamentally new approach, which resulted in the discovery of the flat printed circuit that has radically changed the technology of production. In principle, the same approach subsequently led to the integrated circuits which are now revolutionising radio electronics.

nical control instruments and especially instruments for active control. Specialised production of replacements, spare parts and equipment units, tools, special and standard rigging, and flexible mechanised hand-tools (with electric and pneumatic drive) used in assembly and other fitter operations, should be developed much more rapidly.

Those are some of the important problems produced by the need to develop and introduce automatic processes in the economy.

Automation and the nature of labour. Automation has an exceptional resonance-effect in changing the nature of labour, i.e., the solution of one of the most important socio-economic problems of communist construction.

Involved in the process of material production, man always has fulfilled at least four functions: the first is to set in motion the objects and instruments of labour making use of his muscles as the motive force; the second is to act on the objects of labour by means of various instruments of labour (working tools, machines) by directing and controlling them; the third is to set up and adjust the instruments of labour for the fulfilment of the required operation, and the fourth is to plan and organise the whole process of material production, deciding on the nature of the product of labour (its design), on the labour processes, the instruments of labour to be used and on how the process of production is to run in space and time.[1]

With the invention of the steam engine and then with the development of electrical engineering, the problem of doing away with man's functions as a source of motive power was solved in principle. However, muscular energy still has to be used in the moving of objects of labour before, during and after treatment, in the use of tools by numerous manual workers when servicing and maintaining the instruments of labour in a working state. That is why much importance attaches to the equipment everywhere of all sectors of material production with flexible transportable and movable

[1] Taking part in material production in an epoch in which large-scale machine production prevails, man is also engaged in ensuring the working state of the instruments of labour (motors, transmitting devices in working machines). This also applies to assembly and repair of operating machine-tools and other types of equipment. But the nature of the labour functions performed in these operations turns out to be similar to that performed in the course of the basic production processes.

mechanisms and devices, the supply of motive (electrical or pneumatic) energy to all the manual mechanisms and tools, and equipment of the working machines with devices mechanising all the processes of servicing and control. This becomes possible with the use of the sophisticated individual electric drive and (with the availability of operating units generating electric power) with an automatic supply of the necessary quantities of electric power.

In aggregate, all these measures characterise the *complex mechanisation of production which completes man's full release from the performance of motive-force functions.* It comes before the switch to the automation of production.

Above I mentioned the contradictions between man's psycho-physiological potentialities and the demands made on him by the machinery he controls. This contradiction is resolved through the introduction of a new agent into large-scale machine production, designed to perform the functions of direct control of working instruments. Automatic control devices (first mechanical and driven by electric power, and then electronic) take over the control of working instruments and direct their action on the object of labour. These are qualitatively new instruments of production which signify man's gradual release from direct control of working instruments.

Trends in the development of automation suggest that over a long term there will also be a radical change in man's other functions in the process of production. Self-adjusting automatic systems are already being designed and developed, leaving man to draw up and elaborate programmes controlling the operation of these systems.

Over the long term, there will also be substantial changes in man's fourth function, that of designing and organising the processes of material production. These changes will depend above all on the use of computers in obtaining and processing information, which goes to create conditions for markedly modifying the nature of these operations and, accordingly, of the functions which man has to perform in connection with them.

Consequently, *automation radically changes the nature of labour in the processes of material production and subsequently also in the sphere of mental work.*

Automatic control devices release operators from the functions of directly controlling working machines. Their

work is gradually reduced to the setting up and tuning of automatic machines and lines, supervision of their trouble-free operation, regulation and control of complex automatic systems, and installation and adjustment of new hardware. This will be highly skilled and creative labour, a blend of manual and mental work.

The STR provides the sphere of mental work with hardware and devices that tend to change the nature of the functions performed by workers by brain, for the bulk of whom information is the object and product of labour. They undergo the same evolution as workers in industry at its higher stages. Their functions tend increasingly to be the elaboration of programme for collecting and processing information, ensuring the uninterrupted operation of automatic electronic hardware and analysis of the data-processing results obtained by means of machines. Routine functions give way to creative ones. In this way, there is a process, running from both ends, in which the *essential distinctions between mental and manual work are eliminated and labour becomes socially more homogeneous.*

These radical changes in the nature of labour connected with the advance of the STR, notably the automation of production, confront society with the exceptionally important task of training the required personnel. The rapid scientific and technical progress makes it impossible to limit such training to this or that trade. In present-day conditions industrial workers, technicians and engineers—repeatedly face the need in the course of their working life to switch to a totally new and frequently totally different technology. Consequently, there is a need for extensive polytechnical training which helps to adapt to new and more complex situations.

As I have already said, the boys and girls who were in their eighth year at school in the 1979/80 academic year, will be only 35-36 years old in 2000. They will face the technology of the end of the second and the beginning of the third millennium of our era. I think that the teaching of physics, chemistry and biology in secondary school should give schoolchildren an idea of the fundamentals of present-day and foreseeable technology, so that they should not find it a *terra incognita* in the years of their maturity. I think that schools should also present the fundamentals of cybernetics. The introduction of universal 10-year secondary edu-

cation in the USSR provides an important prerequisite for meeting these demands.

When analysing the revolutionary processes in the instruments of labour, one should not lose sight of yet another and ever more important type of instruments of labour. These are instruments of labour which, like the electronic computer, are designed only to obtain information. These are *measuring instruments and devices*, and generally various appliances specially designed to gain a knowledge of various objects, to measure various parameters characterising the given object and its other characteristics in terms of time, size, weight, temperature and structure.

Seeing, describing and measuring are key conditions for human cognition. The STR and the unprecedented "curiosity" of science, together with the penetration into ever greater depths of being, make ever more complex demands on these conditions of cognition. Without a knowledge and measurement of objects and processes it is impossible to understand them, to say nothing of controlling them.

Optic and radiospectroscopy, electronic and nuclear resonance, electronic and gamma-resonance spectroscopy, neutronography and electronography—all these are methods of the most refined analysis of substances and processes. Methods of luminescent, nuclear-activational, roentgen-structural and mass-spectroscopic analysis, high-speed photography, etc., are being developed.

Instruments using these methods and analyses are ever more extensively applied not only in experimental physics, for which they were primarily designed, but also in chemical, biological, medical and geological research. They are ever more frequently used in the control and automation of production processes. The potentialities of electronics, the offspring of the STR, are used to make electron microscopes, which are already being replaced by proton and ion microscopes. The screening of crystals by means of protons and ions accelerated to energies of tens of millions of electron-volts, makes it possible to produce an express analysis of crystal lattices. This, for its part, is highly important for the production of micromodules which are necessary for fabricating third and fourth-generation computers.

We find here the same dialectics of direct and feed-back connections. The visual and measuring devices being created on the basis of the STR turn out to be a key condition for the further development and acceleration of the STR itself.

The advances in laser technology have opened up fresh potentialities for spectroscopy. Highly sensitive receivers in the infra-red band have made it possible to establish differences in temperature of thousands of a degree. It is becoming possible to obtain heat photographs of various objects in a few seconds, and this helps to solve many important problems in industry, geology, geography and medicine. The temperature "portrait" of a human being is highly important in diagnosing disease.

These are only a few examples, but they show the great importance of measuring devices for solving the most fundamental problems of science, technology and economics.

Finally, *the most convincing and impressive embodiment of the achievements and potentialities of the STR is Soviet space hardware and technology*: ballistic rockets, space vehicles, orbital and inter-planetary stations, and the unique hardware with which they are equipped.

Substantial changes are also taking place under the impact of the STR in the instruments of production designed for agriculture.

The STR will also help to reduce the influence of weather. The extensive use of satellites and space rockets provides the basis for combating impending meteorological calamities.

One also has to note some of the important lines along which the STR exerts an influence on the instruments of labour.

Scientific and technical achievements help to create instruments of labour exerting a *new, much more powerful and effective action on the objects of labour*. In place of the old mechanical methods of action on solids (mainly limited to cutting) there is an extension of methods of plastic deformation, and also physical, physico-chemical, electro-technological, electrono-technological, ultrasonics, blast, plasma, beam and also radiation, nuclear, electrochemical and

chemical methods of acting not only on the form but also on the structure of materials under treatment. In industries with liquid and friable objects of labour there is ever more extensive use, alongside physico-chemical and radiation methods, of biochemical methods, catalysts, enzymes, biostimulators, etc.

The new methods make it possible to create and use continuous-action technological equipment, and also to combine a broad complex of operations in simultaneous action.

The growing unit capacity of technological plant is a characteristic feature and trend in the development of the instruments of labour. Turbines with an annual generation of over 5 billion kwh of electric power, a blast furnace turning out 4 million tons of pig iron, a rolling mill with an annual output of 3-5 million tons of rolled stock, etc., all of this sharply increases the mobility of modern production and makes it more efficient. The increase in the unit capacity of the instruments of labour entails not only an increase in their size—capacity and efficiency—but also a considerable increase in the capacity of forces acting on the objects of labour: the use of high energies, extra pressures, blast energy, great draught efforts, super-high and super-low temperatures, the use of every state of matter, etc.

Progress in solid-state physics has entailed *major advances in miniaturisation and microminiaturisation of many types of equipment*, which helps to increase the capacity and potentialities of technical devices on a scale that is inconceivable with the traditional size of such devices. Microminiaturisation, integral circuits with tremendous capacity, provide the technological basis for the fantastic progress of electronic computers, whose power, speed and capacity have been growing in inverse proportion to their size and weight.

Under the impact of the STR there has emerged and rapidly developed the manufacture of highly productive instruments of labour and technical devices generally to perform processes which have always been the function of workers by brain.

In the socialist society, the application of the STR to the instruments of labour is directly connected with the task of ensuring a high economic and social effect.

This is a complicated problem, especially since the automation of production as a rule runs through a fragmentation

of operations into ever simpler component elements. In industries with discrete processes, this entails the introduction of flow lines with an enforced rhythm, which means that before the whole process is passed over to the automatic machine, labour tends to become even more monotonous and uncreative. There are also many (and frequently more) elements of monotony in running an automatic machine by means of so-called push-button control. Some researchers have discovered what they designate as muscular or sensory starvation.

The design of the organisation of production and labour, especially in batch production and flow-lines, which, as the experience of some Soviet enterprises shows, can be combined with some elements of creativity even for those working on the flow-line, should be seen from the standpoint of harmonising the process of labour with the steadily growing physical and mental requirements of man in the developed socialist society, the man of the communist future. This is the light in which the specialisation and functions of robots should be determined, for in the long term they will have to take over, as far as possible, all the monotonous and uncreative types of work which it is technically impossible or uneconomical to automate in the conventional way.

In tackling the problem of the social effect of technology, considerable importance should apparently attach to creating the conditions for economically appropriate change and conjunction of various types of work. This should also be promoted by the workers' ever broader participation in management, technical R & D and other forms in which their creative activity is expressed.

Such are the most important changes in the instruments of labour arising from the STR.

The STR in action is not only the sum-total of scientific discoveries in the basic and applied sciences and complexes of technical solutions which make it possible radically to change all the key elements of production and products of labour. It is also the embodiment of these potentialities. There are the much larger and renewed production facilities: the powerful and multisectoral engineering which creates new hardware on the necessary scale and which also provides equipment for research, the initial stage in the STR.

However, at every given moment, production facilities and instruments of labour which as a rule reflect an earlier

stage in the development of hardware and production, have a definite and important part to play within the developing and improving production apparatus.

By the beginning of 1978, fixed production assets in the USSR economy were valued at the tremendous amount of 934 billion rubles, with fixed production assets in industry valued at 447 billion rubles.

The socialist state has been steadily building up production facilities in the economy and increasing the share of new assets in them.

In the Tenth Five-Year period, fixed production assets in industry are to go up by 40 per cent, with a steady increase in the share of their active part, machinery and equipment.

The following data show how old the production facilities in the Soviet industry are: of the total fixed production assets in industry on January 1, 1976, 40 per cent were installed in 1971-1975, i.e., were under 5 years old. Of the total installed capacity of electric-power stations on January 1, 1978 (237.8 million kw), 134,7 million kw, or 57 per cent were started in the 12 years from 1966 to 1977. Production facilities in the chemical industry were being built up most intensively. With an output of 98.0 million tons (conventional units) of mineral fertilizers in 1978, facilities for turning out 85.5 million tons were started from 1966 to 1978, for plastics, the figures were respectively 3.51 million and 2.30 million tons, and for chemical fibres, 1.1 million and 665,000 tons.

These data show the high pace at which new fixed production assets are being installed. At the same time, as Soviet statistics show, the pace at which old fixed assets are dismantled continues to be low.

Thus, in 1976, the removal of fixed assets in the industry of the USSR because of obsolescence, wear and tear and natural disasters came to only (as percentage to the fixed assets at the beginning of the year), 1.5, including 2.3 for all types of equipment; in 1977, the figures were, respectively, 1.5 per cent and 2.4.

Add to this the fact that far from all the engineering plants turn out new machinery embodying STR advances and

it will become obvious that the 1980s will be characterised by the existence of machinery based on principles that were uppermost before the full flood of the STR, and machinery based on fundamentally new principles.

That is why the socialist society is faced with the exceptionally important task of developing new instruments of labour and production facilities which accord (with an eye to society's requirements) with the revolutionary advances taking place in science and technology, together with an effort to make the fullest use of the existing production facilities embodying vast masses of past labour, so that the inputs into these production facilities are recouped fully and in relatively short periods of time. This is in tune with the main lines of the coherent technical policy defined by the Communist Party for the present stage in the development of socialism.

Progress in the technical sciences, and the extent and speed with which achievements in the basic sciences are applied in these and, of course, progress in engineering have a key role to play in the solution of these problems.

The development of engineering is an important factor which determines the specific features of the stage of machine production that is to take shape in the final third of this century.

Soviet engineering has scored impressive and generally recognised successes. The USSR turns out the most modern and progressive machines and instruments which are up to the latest scientific and technical standards.

These successes will be seen from the following data reported by the Central Statistical Board under the USSR Council of Ministers.

	New types of machines, equipment, devices and instruments developed				
	1951-1956	1956-1960	1961-1965	1966-1970	1971-1977
Machines, equipment and devices	3,959	10,576	16,626	15,560	20,608
Instruments, means of automation and computers	386	2,326	6,552	5,712	6,670

From 1966 to 1977, over 1,720,000 production-equipment units were modernised at industrial enterprises.

Soviet engineering has mastered the production of a broad range of machines and technical devices realising many achievements of the STR: powerful and superpowerful steam and hydraulic turbines and atomic reactors, unique metal-cutting machine-tools and presses so powerful that they are used to turn graphite into diamonds, laser technology, electronic computers, programme-controlled machine-tools and flow-lines, and so on.

The output of automatic equipment is being intensively increased. On July 1, 1977, all industries already had 20,600 automatic lines, including 10,500 in engineering and metal-working, 3,250 in the food industry, 1,206 in ferrous metallurgy, and 887 in the structural materials industry. From July 1,1965 to July 1, 1977, the number of such lines increased by 240 per cent. Nearly all the power grids of the Soviet Union (96 per cent in terms of capacity) are run from control rooms equipped with telemechanics. The output of the most progressive metal-cutting machine-tools with numerical control went up from 16 in 1960 to 6,300 in 1977. In the manufacture of such machine-tools, which embody many STR achievements, the USSR is ahead of the United States. On July 1, 1977, there were 44,500 units of equipment with programme control in Soviet industry. Thousands of metal-cutting equipment involve the use of the latest STR achievements like ultrasonic, electric-spark and electro-chemical technology, etc. Some enterprises widely use laser technology.

Soviet scientific advances and the high technical standards of engineering make it possible rapidly to develop automated control systems: 414 such systems were developed from 1966 to 1970, and 3,012, from 1971 to 1977. This was made possible by the rapidly growing manufacture of modern computers.

4. THE STR AND THE OBJECTS OF LABOUR

The tasks of further developing the USSR economy and building the material and technical basis of communism make steadily growing and ever more complex demands on the materials used in production.

The economy has a need of ever larger quantities and an ever broader range of primary energy-carriers, organic and inorganic raw and other materials. In the Ninth Five-Year period (1971-1975) the total output of the key materials, as a percentage to the total for the preceding 10 years (1961-1970) was as follows: coal 59, oil 84, gas 93.5, iron ore 69, steel 70, sulphuric acid 89, chemical fibres 95, cement 74. One can easily imagine that over the long term the requirements in raw and other materials of every type will reach huge proportions.

In the Tenth Five-Year period (1976-1980) coal output is to go up to 805 million tons, oil to 640 million tons, gas to 435 billion cub. m. and steel to 168.5 million tons. The output of chemical fibres and cement will be considerably increased. The production of synthetic resins and plastics will double to 5.7 million tons.

There will be an especial increase in demand for structural materials to make machines and instruments for production and everyday purposes, i.e., in the leading modern "triplet": ferrous and nonferrous metals and plastics.

The building up of the material and technical basis of communism will require a multiple increase in production facilities, entailing not only a high level of annual output of various types of equipment but also of total output over a long term allowing the buildup of a stock of mechanisms and technological equipment for every branch of material production that is adequate in terms of technical level and quantity.

The development of a ramified infrastructure—transport communications (railways, highways with improved hard cover, a network of oil and gas pipelines)—and a developed network of communications and mass production of packaging is a highly material-intensive task. Let us note that for the time being the level in the development of these sectors lags markedly behind the requirements of the economy. That is an important cause of sizable losses which are comparable in volume to the required capital investments.

The demand for construction materials is to increase on a tremendous scale.

The task of raising living standards to the highest level in the world entails, alongside an increase in other material benefits, a sharp increase in the provision of household machines and appliances meeting the material and cultural requirements of modern man.

There will be an even greater growth in the demands on the quality characteristics of consumer goods and of capital goods, which is, as a rule, connected with improving the quality of primary materials.

New technical fields require metals and alloys with special physical, chemical and mechanical properties. Pure and super-pure metals, and various possible alloys and compounds have a crucial role to play in the development of new structural materials, which largely determine the further development of machinery.

The basic technological units operate at ever growing speeds, pressures and temperatures, and at ever more intense and critical regimes. Numerous materials of a totally new type are required for modern supersonic jets, missiles, and chemical and many other types of modern plant and equipment, which make a great range of demands on materials. In some instances, there is a need for materials capable of withstanding temperatures as low as 60°-70°C below zero, and in others, temperatures as high as 500°C and over. There arises the need for materials that are more stable than metal while being lighter than water. In some instances they have to be rigid, in others elastic.

Modern technology, especially microelectronics, makes unprecedented demands on the purity of the primary materials. Other problems involve the development of materials with super-high strength, capable of resisting fluidity, materials with a heightened chemical resistance, resistance to radiation, with heightened thermic and dielectrical characteristics, coatings for wires and cables of electric machines and electric transmissions, etc.

This range of demands can be fully met by man-made and synthetic materials, mainly plastics and composite materials.

There is a growing need for low-cost reliable and energy-intensive, hard and liquid types of fuels for jet engines and missiles.

The need for the most effective solution of the problem of materials and the fullest use for this purpose of the potentialities of the STR also springs from the fact that in the USSR the extraction of raw materials and the manufacture of materials demands large-scale resources of living and materialised labour. According to 1969 data (the Eighth Five-Year period), 33 million persons were employed in industries producing raw and other materials (agriculture, the extractive industry and timbering). These industries accounted for 31 per cent of all fixed production assets in the country, and for 26 per cent of all capital investments in the USSR economy. Their share somewhat dropped in the 9th and 10th Five-Year periods, mainly due to reduction in the number of persons employed in agriculture. Savings on raw and other materials and effective solution of the whole problem of the country's raw and other materials balance naturally help to reduce markedly the labour-intensiveness and the assets-intensiveness of the whole of social production, releasing sizable resources for the accelerated development of manufacturing and the non-production sphere.

The solution of the materials' problem requires further development of the production of raw and other materials of natural origin, with a corresponding increase in their exploration and extraction, and also intensive development of the production of man-made and synthetic materials.

The supply of production with the necessary objects of labour in the foreseeable future will require concerted efforts by all the natural sciences, because the STR in this field tends to run at the conjunction of the various sciences.

Joint efforts by the physical, chemical and biological sciences have already yielded a considerable effect. Further progress in research makes it possible to expect that in the foreseeable future there will be mass production of the whole spectrum of materials required for the further growth and improvement of social production.

In view of the rapid growth of production of diverse plastic articles, there arises the need to solve yet another highly important problem relating to environmental protection. Let us bear in mind that the waste of synthetic materials, in contrast to paper, cardboard, glass and metal waste, does not lend itself to recycling, and—and this is especially important—is little if at all decomposible. That

is why the chemical sciences face the most urgent task of developing and arranging the mass production of plastics and synthetic materials which could break up and disintegrate into the original elements within a pre-set period of time. This problem is already being considered by scientists.

The following data show the scale of the advance in the manufacture of polymer materials.

Production of Synthetic Resins and Plastics[1]

	World		USSR	
	mln. tons	per cent of 1950	1,000 tons	per cent of 1950
1950	1.6	100	67	100
1960	6.9	431	312	466
1970	30.0	1,875	1,673	2,496
1974	46.0	2,875	2,498	37.2 (times)
1977	50.0	3,125	3,309	49.4 (times)

Let us note that in the same period plastics output increased as follows: in the United States, from 1,043,000 to 14,800,000 tons, in Japan, from 18,000 to 5,904,000 tons, and in the FRG, from 84,000 to 6,240,000 tons.

The prospects for the production of plastics largely depend on the solution of the problem of developing polymer materials fit for making sufficiently economical (and not more costly than the traditional) structural materials, especially framework and supporting structures. Unless this problem is solved, the growth of plastics production will apparently be slowed down.

Forecasts for the developed capitalist countries give an optimistic assessment of these prospects. Together with the further expansion of the production of metals, which will evidently remain the key structural material until the end of the 20th century, there is to be sustained growth in the output of polymer materials. In the six leading capitalist countries (USA, Japan, FRG,

[1] See *Narodnoye Khozyaistvo* for the respective years.

France, Italy and Britain) the production of synthetic resins and plastics from 1950 to 1973 increased from 1.4 million tons to 30.6 million tons, and is to reach 200 million tons by 1990 (according to the mean of the available forecasts), which is an increase of over 6.5 times. The output of structural plastics for these countries increased from 180,000 tons in 1950 to 4 million tons in 1970, and the forecasts for 1990 put the figure at 40.7 million tons, which means a more than 10-fold increase over a period of 20 years. In the second half of the 1970s and the early 1980s, they expect to increase the output of plastics that could be used for the production of support structures.

On the whole, over a period of 27 years, world output of chemical fibres increased 7.9-fold, and in the USSR—45-fold. There was especially intensive growth in the production of synthetic fibres. In that period, their output in the USSR multiplied 459 times.

Another off-spring of synthetic chemistry is the production of detergents, which in the USSR has virtually been built up from scratch over the past 15 years: from 1,200 tons in 1955 to 824,000 tons in 1977.

The following examples show the great economic effect produced by the use of synthetic materials: the substitution of plastic pipes for steel pipes yields tremendous economies on capital investments, transport expenses (because plastic pipes are several times lighter), on corrosion (plastic pipes are virtually everlasting) and resistance to the flow of liquids (they are much smoother).

The use of synthetic resins as binding agents in casting moulds reduces the inputs of liquid metal by 30-40 per cent and the area of foundry shops by a third, and sharply reduces the volume of the mechanical treatment of castings, and—most importantly—makes it possible to automate the production of casting moulds and of the whole process.

The use of plastics in automobile and aircraft structures helps to reduce their weight by almost a third.

Polymer facing plates, linoleum, and plumbing made of compound plastics, etc., markedly reduce the cost of building and also improve and embellish buildings.

Of exceptional value are polymer film materials in

protecting foodstuffs from damage. The use of plastics in the canning industry helps to save sizable quantities of metal.

The use of polymer materials in agriculture also holds out tremendous potentialities. Thin films which let through UV rays are already being widely used in place of glass in hothouses. Large-volume inflatable storehouses made of two layer films with a nylon-fabric lining are also being introduced.

Everyone knows of the advantages of synthetic materials in the production of consumer goods, like fabrics, clothes and footwear.

Minister of the USSR Chemical Industry L. Kostandov has said that from 1971 to 1975 (Ninth Five-Year period) the use of plastics and synthetic resins helped to release 1.2 million tons of ferrous and nonferrous metals, 4.8 million cub.m. of timber, and 2.9 million tons of other materials. This also helped to reduce the cost of products by 2.3 billion rubles, and labour inputs by over 1 billion man-hours.

Highly promising prospects in the production of polymers are connected with hetero-organic compounds.

The use of silicon-organic polymers for electrical insulation helps to increase the service-life of motors six-eight-fold, and with the same size increases their capacity by 50-60 per cent.

Inorganic polymers could be extensively used in modern missiles and aircraft, in the atomic industry and other fields where the capability of a material to withstand high temperatures is the basic criterion of suitability.

Films made of so-called ethyl silicate are used for the high-precision casting of metals, for they have high heat-resistance and withstand contact with molten metals, so that they can be used to make excellent casting moulds. Castings from such moulds require virtually no subsequent mechanical treatment.

Synthetic materials can have a big part to play as substitutes for food raw materials used in making some industrial semi-finished products.

Despite the exceptionally rapid pace in the output of light metals, mainly aluminium, and the even faster expan

sion of the production of polymer materials, ferrous metals, steel in the first place, continue to top the list of structural materials. Here, one should bear in mind that far from all plastics (and not even the bulk of them) can be used as structural materials. According to available publications, structural plastics make up only 20 per cent of the total consumption of plastics. Thus, only about 45 kilograms of plastics go on average into one car in the United States. Sizable quantities of them are used in building, etc.

> In 1976, the developed capitalist countries produced 414 million tons of steel, 9.6 million tons of aluminium, 246,000 tons of magnesium (1975) and 38.9 million tons of synthetic resins and plastics. If these weights are calculated into volume, taking into account the specific weight, the following percentages are obtained for the production of these key materials: steel 68 per cent, plastics 29 per cent, aluminium 3 per cent, and magnesium 0.05 per cent.

Let me add that in the bloodless battles against chemical materials, ferrous metals are not at all "retreating" without a fight. They are "battling" for their place, and their chief weapon is larger range and higher quality.

Alongside the competition between metals and polymer materials there has also been evidence of "peaceful coexistence" between these rivals. This is expressed in the rapid development of composite materials, or composites, as they are also called.

In an article entitled "Material of the Future", Academician Y. Rabotnov says: "Composites are a totally new chapter in material science. And while success here is achieved at the cost of intense efforts by the whole army of researchers, the pages of this chapter are being rapidly filled with facts. The success of the undertaking is beyond doubt. Experts predict that by the year 2000 structures based on homogeneous materials will simply be unable to compete with composites".[1]

Technology increasingly requires materials with a combination of useful properties each of which is inherent in some natural material, and which is, as a rule, absent in natural

[1] *Izvestia*, February 4, 1974.

materials in the given combination. At the same time, it is nature that has suggested ways of solving the problem. Timber, bamboo and bone are so durable because they are composites of soft and hard components. Reinforced concrete, the extensively used composite, consists of concrete which is designed for compression, and steel reinforcement which is designed for tension.

Radio-transparent and radio-absorbing composites have now been developed as "hybrids" with magnetic, dielectric and other special properties, something that could not be done with conventional alloys by means of the traditional efforts.

Composites based on hydrocarbon fibres—carbon plastics—have remarkable combinations of properties. They are light while being highly durable and rigid. Parts of aircraft are already being made of carbon plastics. As the output of composites is increased and their costs reduced, they will be used more extensively in the structures of automobiles, ships and buildings.

Composites are also of fundamental importance because they create the conditions for the actual design of materials with pre-set properties. They make it possible to go over to "optimal designing", so that the structure is light, low-cost, durable and rigid, in strictly determined places of the structures, without any excess or reserve, but with great precision at the right place.

Alongside the developing production of existing and various new materials of natural and synthetic origin, *the STR opens up broad possibilities for the physico-chemical influence on the structure and property of materials.*

The problem of action by penetrating radiation with the aim of modifying the basic properties of metals and alloys has already been solved in technical terms.

The revolution in materials is becoming an active factor exerting an influence on all the elements of production. One need merely refer to the discovery and rapid development of mass production of semiconductors, which have literally revolutionised electronics and made it more mobile, light, accessible and very much more reliable. Without semiconductors there would have been no rapid miniaturisation, no second-generation computers, no massive and portable everyday electronics, or such rapid progress in technical control devices.

The next stage, which was a major qualitative leap, was connected with the emergence of integrated, and then of large integrated circuits, the basis of microminiaturisation, the development of computers of the following generations, mini and microcomputers, marking a new stage in the automation of production; this stage was connected with the introduction of microcomputers into transport facilities, and the mass production of low-cost electronic calculators which are a real revolution in practical calculation.

Truly revolutionary prospects for the development of micro-electronics and possibly for a number of other sectors of material production are connected with the already developed technology for growing large single-crystal silicon chips without any dislocations.

They are already used in highly diverse fields:

—large integrated circuits are used for developing new generations of computers and are based on crystals artificially grown in definite conditions;

— physical instruments capable of withstanding the influence of aggressive environments, penetrating radiation, high temperatures and pressures, which include heat-proof single crystals;

— the rapid development of laser technology, non-linear optics and other modern lines in science and technology was made possible by the growth of large crystals with remarkable optical properties.

In the recent period, the task has arisen of developing a "crystal computer", the crystal not being homogeneous in terms of its "cells", i.e., a single crystal whose structural cells have dissimilar properties throughout the whole volume. The operation of the "cells" organised in time and space produces the desired result: the solution of some computing problem, the problem of regulating a technological process, etc.

The development of such a crystal-computer is an exceptionally complicated technological problem, for its size is measured in millimetres, while the number of "cells"—logic circuits and memory circuits—runs to tens of thousands.

The US press reported that in the United States a group of scientists led by Nobel Prize winner Leo Esaki has developed artificial structures, crystals which do not exist in nature—"super-lattices"; their laminated lattice structure

has a period (distance between layers) of about 3-5 nanometers (1 nanometer equals 10^{-9} m, i.e., one-millionth of a millimeter); their production is controlled by means of a computer. One cubic millimeter of such a crystal will hold up to 10^{18} cells, a billion billions. One specialist said that nano-electronics is being borne instead of microelectronics before our very eyes.

We are considering STR problems in materials, the objects of labour. But an important distinctive feature of the STR is the obliteration of the traditional boundaries between the individual elements of production, their displacement and interpenetration of each other.

The crystal computer helps to reduce the cost of the "electronic brain" to a point at which the tiniest production "elements" can be converted into "thinking machines". They help to speed up the operation of automated plant by linking up "thinking" production machines, transducers and other instruments in a ramified system for the collection of information and control. In a hierarchical system, the microprocessors in the "thinking" production machines are linked up with the control minicomputers collecting information and transmitting it to the central computer of the plant. At the top of this system is the head computer, which is connected with the plant systems and can report, on the basis of the latest information, on the state of affairs as a whole.

The present cost of microprocessor regulators has helped to cut the cost of control systems down to nearly 1 per cent of the old figure. The microprocessor is now being introduced into a wide range of goods.

An in-flight device is being tested which is fed with data on the height, the flight weight of the aircraft, the air temperature outside, and the compression in the engines, and tells the pilot at what height he should fly to save from two to five per cent of the fuel.

The objects of labour, which over the centuries have been the most conservative elements of production, are now becoming one of the most dynamic element as a result of the current STR. Once a rigid constraint on the economy because of the quantity and structure of available natural resources, the objects of labour have been gradually developing into a genuine object and product of human creativity, which invests them with preset properties and combinations

of these. Men are enabled ever more fully to protect natural resources, especially those which are not renewable.

At the same time, there is the growing problem of producing a strategy for the *optimal blending of the whole incredibly broad range of natural and synthetic materials, and the development and realisation of an optimal balance of raw and other materials in the economy.*

A highly important problem, especially in the conditions of the USSR, is to enhance the efficiency of the whole sphere of production of the objects of labour, its technical re-equipment, and a boosting of labour productivity in this most labour-intensive and capital-intensive sector of the economy.

Finally, primary importance attaches to the problem of reducing the material intensiveness of social production both by enhancing efficiency and improving the quality of the final product in the extraction of raw materials and the production of other materials, and through their more efficient use by users as they improve the design, technological and organisational conditions and solutions in production.

5. REVOLUTIONARY CHANGES IN TECHNIQUES

Before going on to analyse the influence of the STR on the production techniques, there is a need to define the content of this category.

Techniques is not an immediate material element of production, although indirectly, through material elements, it exerts a substantial influence on it.

I think that Academician N. Zhavoronkov has given a scientific definition of techniques in the light of its special-purpose function. He regards techniques as a science "about the most economical methods and processes for the conversion of raw materials into the objects of consumption and the means of production. Technological processes are those in the course of which the processed material undergoes a qualitative change."[1]

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[1] *Nauka i zhizn*, No. 4, 1970, p. 71.

In a functional definition of techniques, one could say that it determines the means and objects of labour, the regimes of their work and use, and their combinations in time and space that could yield the given product. Consequently, *techniques determines the whole purposeful course of the production process, including both the nature of the technological operations proper, and the operations of transportation, movement and technical control.*

Back in the first half of the 20th century, technology was, as a rule, simply determined by the products of labour and the means of production. Scientific and technical progress has not only added complexity to production methods, but has also made it multivariant, so doing away with the erstwhile straightforwardness.

What is more, with the vastly increased potentialities of technology and the growing impact of methods on the property of the materials produced, the latter increasingly become independent of the availability of instruments and objects of labour, independent and ever more active element of production and, accordingly, objects of research and design. The instruments of labour were traditionally regarded as the active element of the means of production, but in the epoch of the STR techniques becomes an equally active element in some instances; ever more frequently it is the conduit along which science penetrates into production, often working a radical change in the means of production in the process: the continuous casting of steel does away with the giant blooming mills, new welding methods eliminate giant surfacing lathes, etc.

All of this makes it necessary to designate techniques as a special element of modern production. As research passes through the development stage, its results are ever more frequently embodied in technological solutions which now and again become the starting point for the design of production itself and of all its basic material elements.

This role of techniques in modern production naturally determines the exceptionally great impact which the STR has on it. Advance in research, and development based on it increasingly influence production and penetrate into it precisely through new production methods. There is good reason why some are inclined to regard the switch to the new method, that is, the switch from discrete and multi-operational processes of mechanical treatment to continuous com-

puter-controlled processes based on physico-mechanical, electro-physical, physico-chemical and biological principles as the synthetic indicator of the STR.

A characterisation of the techniques of material production which took shape by the mid-20th century requires above all a grouping of the existing industries into groups which are more or less homogeneous in technological terms.

The following groups may be brought out:

The extractive industries. These have the common feature of having highly capital-intensive and labour-intensive processes of extraction and movement of vast masses of the natural substance, and also ancillary processes of fixture (timbering) of the rock containing the useful minerals, and action on them.

Industries with continuous production processes (*electric power, metallurgy, chemistry and oil refining, pulp-and-paper, cement, some food industries, and, with some peculiarities, the textile industry*). The content and result of the production process in most of these industries is transformation of the substance (or an aggregation of various substances) or the production of new substances. Techniques here is, as a rule, based on high temperatures, high pressures and related chemical reactions, and physical and physico-chemical transformations.

Industries with discrete production processes (engineering, wood-working, garment- and footwear-making, building, etc.). Here the production methods, are, as a rule, based on shaping by mechanical methods and also the mechanical bonding of individual components into the final product.

Industries with a prevalence of bio-organic processes: agriculture and some food industries. The main thing here is: cropping and stock-breeding, biological, chemical and mechanical action on these processes, and the use of biological processes for obtaining some products. An important role here belongs to genetics and selection, which help to improve the original means of production—seeds and animals—and also a complex of agronomic and industrial measures helping to improve another means-of-production group: the land, the farmland, and feed for the productive animals.

The STR introduces the most radical changes into the production techniques of these four groups of industries.

In the first group, continuous processes for underground extraction are being introduced for the purposes of their broadest automation. Remote control will make it possible gradually to switch to a method of extraction without the participation of man. An increase in the power of the technology being used, given definite conditions of the mineral bedding, makes it easier to switch from underground (mine and pit extraction) to open-cast mining, under which there is a marked improvement and easing of working conditions and a rise in labour productivity.

The most radical changes are connected with a switch from the now prevalent mechanical extraction of minerals to a fundamentally new method: underground chemical leaching, thermal sublimation, underground electrolysis, underground gasification of coal, etc. These methods are highly efficient because they make it possible to use deep-lying and low-grade ores.

The changes in the techniques of the second group of industries are characterised above all by the use of new sources of energy, notably atomic energy.

The next trend characterising changes in the production processes of this group of industries is the marked intensification of existing processes: oxygen blast in metallurgy, catalysts in chemistry and oil refining, enzymes in the food industry, etc.

Just now, there is a return—naturally, on a new and much higher basis—to the method of obtaining metals through direct reduction of iron, which excludes the blast-furnace process.

Despite the fact that modern metallurgy now has in use continuous-type units, all production processes characteristically remain discrete. This produces the need to equip mills with giant rail transport, to heat the metal again and again—first in the blast furnaces, then in the mixers, in the steel-smelting units and finally before rolling. All of this involves tremendous energy inputs. There is no need to show how such a technology tends to increase the cost and complexity of the production of metal.

The solution of this complex of problems, evidently, requires a *switch to a process of the continuous production of metal.* The extensive use in Soviet metallurgy of continuous steel-casting installations, on the basis of the successes in solid-state physics, has done much to solve this problem.

Work is now under way on a totally continuous metallurgical process.

The use of super-low and super-high temperatures and pressures, super-high speeds of movement of the reacting components, chemical synthesis from pure and super-pure original substances, all of which mean the use of extreme parameters in production processes, is a key trend in the development of chemistry. In view of these peculiarities and the need to ensure optimal conditions and regimes, one could say that such processes, as they are intensified, will require automation and the use of cybernetic hardware, like modelling, computing and controlling devices, and devices for self-tuning to optimal regimes. Projects for such technological processes in chemical-type production are already being developed.

The complex use of raw materials and energy is a key line in the development of chemical processes, and this is one of the essential factors not only in enhancing the efficiency of production, but also in preventing air and water pollution.

This entails a gradual introduction in every industry of closed-cycle technological processes which eliminate all waste and discards, and a switch to waste-free technology. Academician Zhavoronkov writes: "A technological process cannot be regarded as complete and perfect if it entails discards and wa e, if it is periodical and if it does not run at optimal parameie .

The STR exerts an especially diverse influence on technological processes in the third group of industries, and this is expressed above all in the use of fundamentally new means of acting on the objects of labour.

Although the old, traditional ways of metal treatment, like cutting, stamping, forging and casting, continue to prevail in engineering, even here the techniques has been undergoing marked changes. In mass production, extensive use is being made of chill, permanent-mould casting, casting under pressure and other progressive methods. There is use of automatic machines and transfer lines, sometimes involving remote control.

The achievements of the STR also make it possible to develop fundamentally new technological methods. In the USSR, there is extensive use of hydraulic modes of shaping, where

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[1] *Nauka i zhizn*, No. 4, 1970, p. 75.

liquid is the working element. Photohydraulics, a new way of metal treatment, has emerged on the basis of research in quantum physics. A ray of light, interacting with a liquid, is capable of producing tremendous pressures, generating a powerful blast as a result of which the liquid acts on the material and shapes it into the required form. The purity of the surface and the precision are so great that in most instances such items do not even require any subsequent grinding or polishing.

Among the fundamentally new means of acting on the objects of labour are techniques involving the use of heavy and light currents, high magnetic fields, ultrasonic oscillations, plasma and the rays of quantum generators, electrochemical action, and highly concentrated chemical solutions.

The use of most of these entails a substitution of cutting by methods of plastic deformation and three-dimensional chemical shaping, both of which produce a sizeable economic effect. The new technological methods tend to make the process of metal treatment ever more continuous.

The impact of the STR on the production methods in the fourth group of industries could increase over the long term because of the steady advance in the biological sciences, their penetration into the fundamentals of organic life and the growing possibilities of exerting an influence on such processes.

The advance of selection in cropping, with due development and material back-up, makes it possible to develop highly productive strains of food and feed crops resistant to zonal weather conditions and lodging, and yielding a final product that is chemically balanced. Together with a complex of agrotechnical measures, land improvement and the introduction of a progressive machine system, this could ensure permanently high yields. The development of a powerful mixed-feed and biological industry could help sharply to enhance the efficiency of feeds.

Advances in genetics and selection and the consistent specialisation of productive animals and fowl, the switch to industrial technology and the marked acceleration of the process of their breeding, the use of industrially processed feeds—all these measures, together with the introduction of a machine system and a development of the infrastructure, especially transport, elevators and storage space, will help

sharply to raise yields and productivity in agricultural production.

The STR not only generates new technological processes, but also shapes the key material prerequisites for their use. Among these are methods for enhancing the qualitative characteristics of metals, the development of new polymer materials with properties that allow better treatment, and also of composite materials. Finally, advances in solid-state physics make it possible to develop new synthetic materials for obtaining immensely more progressive tools like artificial diamonds.

Advances in atomic physics and atomic-power generation have made it possible to use the fundamentally new, radiation processes in which the latter are effected under the action of gamma rays, charged particles and splinters produced in the fission of the nucleus. The advantage of these processes consists in the possibility of energy-intensive treatment, without the use of high temperatures or pressures, in the possibility of changing the structure of matter and in completely mechanising and automating the whole technological process.

Radiation processes are being ever more extensively used in the most diverse sectors of the economy, as in the chemical industry in the polymerisation, modification and synthesis of various polymer materials, in the production of fertilizers, fibres, detergents, catalysts, etc.; in oil refining, in the synthesis of chlorocarbon additives to lubricants to obtain paraffin hydrocarbons containing chlorine, etc.; in radio-electronics to obtain semiconductor materials with preset properties; in wood-working to obtain plastic-and-wood materials; in the textile industry in the production of high-quality fabrics that are water-resistant, easily washable, etc; in the food industry in the pasteurisation and sterilisation of products, and in lengthening their shelf-life; in agriculture to enhance the quality of various crops, to combat pests and increase the storage life of many products.

One has to note that despite the obvious high efficiency of the processes of radiation technology, the production of the necessary equipment for its use has so far been inadequate.

Consequently, the advance of the STR creates more and more new progressive technological methods which immensely multiply the potentialities of material production and enhance its efficiency.

6. SCIENTIFIC AND TECHNICAL PROGRESS AND ECOLOGY

There is yet another exceptionally important aspect to the STR and the technology of production, namely, their impact on the environment. The rapid growth of material production, as the tremendous potentialities of the STR are realised, has had an ever more radical global impact on the biosphere, land, water, air, flora and fauna of the Earth.

This has produced a rapidly developing branch of the biological sciences, ecology, which deals with interaction between the organism and its environment with all its inorganic (abiotic) and organic (biotic) components.[1]

The well-known US ecologist Eugene Odum has defined ecology as "environmental biology".

Earlier on, I presented the views of the prominent Soviet biologist, Academician V. A. Engelgardt, concerning the trend in the development of biology towards integratism, "towards levels of increasing complexity of organisation, towards systems acquiring new properties and functions". Ecology is one of these integral (high-level) sciences of the biological complex. From the study of the structure and processes in organisms, ecology goes on to a study of major and even global biological systems in which individual organisms are united in a single whole: it concentrates on a study of the connections between organisms and their habitat and other organisms of the organic world. Consequently, it is in a sense a synthesis of the biological sciences and other natural sciences.

With the acceleration of scientific and technical progress and its application in practice, together with its growing impact on the surrounding world, ecology moves to the forefront of the natural sciences and comes ever more vigorously to interact with all the sciences, with technology and production.

Let us bear in mind that some of the after-effects of scientific and technical progress that have been traced and those which are already quite foreseeable are highly negative and show that ecological problems are now of key importance and must be taken comprehensively and scrupulously into

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[1] See I. Sutokskaya, "Ecology and the 20th Century", *Nauka i zhizn*, No. 7, 1978.

account when tackling any problems of technical, structural and economic policy as a whole.

In this sphere, we find fundamental distinctions in the socio-economic after-effects of scientific and technical progress in countries with different social systems.

The Earth and its biosphere are a large and complex system, each of whose subsystems and units are closely interconnected. The ecological equilibrium which we find in nature is very sensitive to changes in any of its components. Failure to estimate this sensitivity and isolated, instead of systemic, solution of any problem could produce unforeseen and dangerous consequences.

The use of nature and protection of the environment are a complex of diverse and inter-related problems of which the most important are:

the fullest complex use of non-renewable natural resources, mineral fuels and raw materials above all;

the complex use and rational renewal and—wherever possible—expanded reproduction of natural resources: land, forest, flora, fauna and water;

introduction of closed technological cycles and the fullest use of production waste and protection against pollution of the environment;

maintenance of the ecological equilibrium on the surface and in the biosphere of the Earth.

In the industrially developed capitalist countries ecological problems are most acute, and this has now been realised by scientists and statesmen in many countries.

"Is it possible to save Spaceship Earth?", is the title of an article in the West German *Der Stern* by Ulrich Schippke, who has published a number of works on prognostications in science, technology and production. He gives the following imaginative description of the state of affairs: "Spaceship of mankind—Earth-1—now has on board 3.6 billion passengers. At their disposal are 5 quadrillion ($5 \cdot 10^{15}$) tons of air and 1.3 billion cub. km. of water, of which only 2 per cent is fresh water. Earth-1 is hurtling at 30 km per second, i.e., at about 1 billion km per year.

"For the first time in its long peregrinations, signs of a mortal danger have appeared. The ship is overloaded. One-half of the passengers are starving.[1] Vital stores are running out."

[1] This is a patently unscientific, one could say, Malthusian, approach on Schippke's part. The fact that a sizable part of the world's

In 1970, an effort was made in the United States to assess the losses from air pollution, but no account was taken of the pollution or the cost of eliminating solid waste. The losses were estimated at $ 12.3 billion a year, with the falling value of real estate and the cost of restoring it coming to $ 5.8 billion; the destruction of machinery plant and materials was assessed at $ 1.7 billion, and the harm done to human health, at $ 4.6 billion.

The Soviet Academician E. K. Fyodorov, in his work *Society's Interaction with Nature*, presents numerous and convincing data showing the irreparable harm being done to the biosphere in the developed capitalist countries.

In the United States, the annual consumption of raw materials comes to about 5 billion tons, half of which is structural materials. This means that on the territory of the country something like 18 tons of waste per hectare is accumulated every year, or goes down into its rivers or up into the atmosphere.

According to Barry Commoner, in his *The Closing Circle* (1972), the 40 per cent growth in the population since 1946 was accompanied by a roughly 10-fold increase in pollution, which means seven times per head. Here the important thing is not the growth of the population but the technology and the social conditions.

Pollution of the atmosphere already has a negative effect on human health. Thus, nearly 35 per cent of the inhabitants who were screened in the industrial area of Tokyo suffer from grave lung diseases caused mainly by air pollution.

Intensive work is being carried on in the Soviet Union to introduce waste-free processing of raw materials and the use of waste. According to the data of the Leningrad Technical Institute, production processes involving the complex use of raw materials are already being used at the Slantsy combine, at the Lenin Soda Works in Lisichansk, and the Nevinnomyssk Chemical combine, while the Achinsk oil refinery has been de-

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population is hungry is not due to some "overloading" of Spaceship Earth, but results directly and largely from capitalist social relations.

signed for a closed water cycle, which means that it has no effluents.

There is experience of using in hot-houses the carbon dioxide, which usually goes up the chimney into the air. Inorganic compounds of nitrogen and phosphorus contained in industrial effluents are an excellent substratum for growing unicellular algae. Phenylic acid effluents from most petrochemical plants are a nutrient medium for fodder yeast, etc.

The arms race, the testing of modern weapons and wars started by imperialism in various parts of the globe have a negative effect on the environment. Academician Fyodorov is quite right in saying that while many Western scientists and public figures are aware of industrial pollution, most of them do not give due attention to the pollution arising from war.

It is known, that the testing of nuclear weapons could lead to the leakage of chemical and poisonous substances. The press has reported the loss by the US Air Force of nuclear bombs off the coast of Greenland and at Palomares.

By 1970, the use of chemical weapons in Vietnam had resulted in the destruction of over 25 per cent of South Vietnam's forests, thousands of hectares of rubber plantations, and hundreds of thousands of hectares of rice paddies. From 1961 to 1969, 1.3 million people suffered from poisonous substances. 185,000 persons were poisoned in 1970 alone. There are many other similar examples.

There is hardly any need to explain what would happen to the globe in the event of a nuclear war. Atomic and thermonuclear weapons could wipe out life on the Earth. Similarly disastrous consequences could result from the use of bacteriological and chemical weapons. This shows the great importance of the agreements on scientific and technical cooperation in the peaceful uses of atomic energy signed by the USSR and the United States in 1973.

Of course, the socialist countries also face environmental problems and the need to avert any possible negative effects from production, but under socialism these problems are tackled in a comprehensive way.

In solving ecological problems, Soviet scientists and the Soviet state on the whole take the social-optimism view and start from principles characteristic of the current STR. We have formulated these principles in characterising the content and specific features of the STR: *from analysis and explanation to synthesis and control.*

To seek to protect Nature and the biosphere by refraining from exerting an influence on them would amount to stemming progress and abandoning the vigorous and creative activity which is becoming a necessary component of mankind's creative endeavour, and one of the greatest values that men have won in the process of their evolution and self-improvement. Academician Fyodorov was quite right in saying: "Only a primitive tribe subsisting on the collection of fruits and hunting of animals could exist in a strict 'natural equilibrium'. If our ancestors had converted our planet into a well-protected reserve, modern civilisation would simply not be there... The suggestions that technical progress inevitably leads to a degradation of Nature are equally unfounded. Progress is to blame for this as much as for the development of mass destruction weapons. The point is not the technology, but how and by whom it is used".

This produces the task of going to the *projection of Nature.* Soviet scientists propose that ecology's role and functions should be extended. Academician Fyodorov says: "It is this science of the Earth that is designed ... to work out on the basis of a complex analysis of the data from various disciplines the resulting assessments of the consequences both of deliberate influence on the environment and the purposeful transformation of Nature".

Quite naturally, the chief and most difficult elements of such assessments consist in the calculation and prognostication of future events in Nature owing both to the development of natural processes and to the results of deliberate or purposeful influence.

The present level in the development of the physico-mathematical sciences and the STR-induced cybernetic—modelling (analog)—devices and computers make it possible to solve this problem, which is perhaps the most global and complicated one in the whole complex of the sciences of the Earth, which is to work out scientifically grounded methods for *reliable modelling and computation of future states of the natural environment.*

Many elements of these prognostications are already being realised. The service prognosticating the state of the ionosphere has been functioning for nearly 30 years; services for monitoring and prognosticating the state of radiation in outer space were recently set up in the USSR and the United States. Seismological forecasts are at hand.

Some biological processes are already being prognosticated, like the state of agricultural crops, the harvest, the period in which agricultural pests appear, the movement of schools of fish in the ocean, etc.

The switch to the prognostication and the "programming" of Nature is a most difficult task requiring the formulation and solution of a broad range of sub-problems.

The task of medical scientists and biologists is to calculate the limits of tolerable concentrations of a wide range of substances for humans, animals and plants. This is a complexity of the problem because such calculations proceed from the direct effect of the given substance on the human organism or plant, but the fact is that in practice many substances from different sources act simultaneously, enter into reaction with each other and form new compounds.

We find the same thing in the air. Academician Fyodorov writes: "In every process of interaction of a given element with the environment and then with the living organism there is a need to reckon with the possibility of appearance of unstable states and chain reactions when the effect of the action loses its earlier, for instance, linear, dependence on the concentration of the element and changes sharply with an insignificant increase in the concentration".

The complexity of these problems is multiplied (and in a non-linear way, at that) by the diversity of the ties existing in the environment. The reduction in or disappearance of a population of some animal or plant as a result of environmental pollution inevitably leads to the accelerated propagation of another species which used to serve as food for the former, a reduction in the numbers of the species which had fed on it, etc.

Meanwhile, among the man-made compounds there are some for which natural communities have not been prepared by the whole course of evolution. The outcome of the "struggle" of these new compounds with Nature and its inhabitants depends on the sensitivity of the latter. That is something

mankind must be prepared to deal with and to provide for measures to prevent any negative consequences.

Here is what I. Sutokskaya, Cand. Sc. (Biol.), says on this score: "With a knowledge of how the pollutant is included in the metabolism of the microbe cell and what its role in this metabolism is, it is possible to produce appropiate additives to chemical substances to accelerate biological disintegration in the natural environment. Finally, it is possible to replace many of the stable substances now used with those which disintegrate rapidly and are, for that reason, not accumulated in the soil, water or living organisms."[1]

The task is to learn to model the whole complex of changes in the environment, of all these "effects", reactions, arising on a local or even a global scale. Academician Fyodorov writes: "Will science be able to cope with these tasks? It has to and is already doing so.

"The unexpected nature of many of the negative effects from the spread of some substances in the natural environment is due, we think, not to the specific complexity of the scientific problems which arise in this connection, but to the fact that for a long time science simply did not deal with them."

In this context, there was one proposal for the development of a mathematical model of the existing climate and ways of computing its possible transformations under the impact of unpremediated or deliberate human action. Chemists working with organic or inorganic synthesis face this task: when projecting each new substance to decide what is to happen to the articles made from it, once they have served their purpose. This will help to include the newly developed substances in natural geochemical cycles, say when, as fertilizers, they are used as secondary raw materials for subsequent production in new articles, as structural materials, etc. Academician Fyodorov sums up: "There is only one way out, and that is to formulate the principles and methods for restructuring ecological chains and creating new but closed cycles for substances, and of creating combined material and man-made chains in ecological systems".

All of these tasks should serve as criteria in the development of substances, technology and production complexes.

That is the view taken by Soviet scientists of the highest

[1] *Nauka i zhizn*, No. 7, 1978, p. 17.

stage in the development of the STR: transition from analysis and the explanation of the processes going forward in Nature to their prognostication, programming and active influence on them, and ultimately their projection.

This also determines the approach to the solution of any scientific, technical and production problems. Mankind must alter its very approach to Nature: from *the use of it and its products*, one has to go on *to cooperation with it*, which means that mankind must project and carry on its economic activity in accordance with Nature's potentialities.

The protection of Nature and the preservation and utmost improvement of the environment are a key component part of state policy in the USSR. These matters were dealt with at a special session of the USSR Supreme Soviet, whose decisions envisage the establishment of an all-embracing and exhaustive *system of state standards for the protection of Nature.*

The first few standards of this system have already been worked out. In 1978, State All-Union Standards were approved for the section entitled "Atmosphere", which are aimed to maintain the purity of the air and which establish the procedures for monitoring and controlling the emission of noxious substances into the atmosphere by industrial enterprises. Other standards in this section list and establish the corresponding standards for the emission of gases into the atmosphere by automobile and tractor engines. Special control is established over carbon monoxide.

The standards in the section called "Hydrosphere" dealing with the sea water pollution during the drilling of oil wells are about to be approved. The standards provide recommendation as to how to choose the place for drilling, build and work the see-bed drilling platform. Special standard of this sector is dedicated to the preservation of purity of rivers and fish during the timber rafting.

The approved standards in the section entitled "The Earth", which regulate the procedures for recultivation and renewal of lands damaged in the digging of trenches, pits, etc.

Standards in the section entitled "Flora" are connected with the rational use of land zones in cities, which are subdivided into forest parks and commercial forests, each with a regime of its own. Great attention is given to the establishment of man-made watering-places, the feeding of birds

and beasts, the establishment of "fauna rest zones", the spread of ant-hills, etc.

According to T. N. Lyamin, a member of the State Committee for Standards of the USSR Council of Ministers, "just over 20 standards in the system for the protection of Nature have now been framed, and the number is to double by 1980. But the basic and most laborious part of the work naturally lies ahead. After all, we are trying to produce an exhaustive 'code of Nature' and that is not easy.

"The new system is not only coherent and complete but also highly complicated, for it involves the expression in mathematical calculations and laconic rules of the most diverse relations between man and Mother Nature, which have taken shape over millions of years, a task that can be tackled only by specialists of the highest qualification, who have at their disposal facilities offered by the developed socialist society and the broadest support of the state".[1]

Work on the system of standards for the protection of Nature is being carried on by the USSR Academy of Sciences, the academies of sciences of the Union Republics, leading scientists at 147 research institutes and specialists from 38 ministries and departments. The protection of Nature is an undertaking for the whole people.

Highly important and productive research is being done in the USSR in the use of production waste.

A group of scientists in the city of Zaporozhye has set up a non-payroll laboratory for the protection of Nature and the ecologisation of production. They believe that waste is not a matter that is foreign to Nature because it consists of the same atoms as the surrounding world. But man has combined these atoms in a way to which Nature has not adapted itself in the course of evolution. Accordingly, they set the task of turning mankind's economic activity into an element of the natural circulation of substances in Nature.

Professor Vassily Kuchin says: "Man's relations with Nature must be so arranged that the waste from our activity should become full-fledged raw materials for the following cycle in the circulation of substances.

"Organic and inorganic worlds are continuous production mechanisms which have proved their viability in the geological time-scale, in which waste and each population in

[1] *Nauka i zhizn.* No. 7, 1978, pp. 8-9.

itself serve as resources for other populations, and consequently, as vitally necessary phases in the age-long natural biochemical exchange and circulation of substances.

"From this standpoint, the sequence of natural resources—products—waste, which is characteristic of present-day production is unnatural because it ends with the destruction of natural bodies and systems. It is absolutely necessary to add another phase to man-made production: waste—natural raw materials, for this alone will help to close the circuit broken by man in the ceaselessly alternating transitions of matter through the stages of life and death, through its organic and inorganic forms."

The scientists have tried to model such a closed circuit. There are many plants and factories in Zaporozhye, and analysis showed that they have to get rid of 66 aggressive substances.

The idea is that these substances should be invested with a form in which Nature would recognise them as "its own".

To verify the idea, specimens of all the waste were collected and mixed in a small chamber (reactor) in proportions corresponding to the proportions in which the substances are emitted on the scale of the city.

Quite naturally, a spontaneous process of the mutual neutralisation of the waste at once began in the reactor. Acids reacted with alkalies, there were processes of dissolution and sedimentation, in short, something similar to geochemical processes got under way.

When the system reached a state of equilibrium, the substances obtained were analysed. The gaseous medium which had been formed turned out to be close in composition to that of air. The liquid part of the products resembled sea water, and the sediments looked like clay. In short, the result was a more or less neutral inorganic mass.

But it had to be established that this mass was fit to be assimilated by plants and living beings.

With the help of scientists from the Institute of Biology of the Southern Seas of the Ukrainian Academy of Sciences, the "sea water" was populated with ever more complex forms of marine organisms. After a month, it was evident that the lower organisms spawned, while the sea-weed and molluscs were acclimatised.

Seeds of barley, wheat, sugar-beet, cucumbers and other plants were sown into the "clay", and all struck root, with

barley growing and developing best of all. On four-year "clay", it was markedly better than control sowings.

An analysis of the "air" confirmed that there were no aggressive gases in it, there being only an excess of components containing carbon.

Professor Konstantin Skufyin, says: "Please, note one important fact: when the experiment was being prepared no task was set of obtaining final products 'acceptable' to Nature. The initial substances and the proportions in which they were mixed were determined largely by accident: they turned out to be pre-set by the structure of the industrial complex which had taken shape in Zaporozhye. But even this casual set of components has yielded fairly good results.

"If the ultimate goal is to obtain solid, liquid and gaseous phases with definite characteristics, the conditions of the experiment would have to be changed. To the casual components (waste) which are determined by the structure of this or that industrial complex, one would have to add a set of special, one could say, 'alloying' additives to compensate for the absence of some substances in the original set of components."

That was the origin of the idea to create a "resource-producing economy" on the basis of the potentialities of the STR. Here is how it is described by engineer Aleksei Nagorny, who heads the laboratory at Zaporozhye. "It consists in supplementing the industrial complexes taking shape in some regions with yet another unit, a special physico-chemico-biological combine, 'working up' everything that remains at the base enterprises and converting their waste into forms that do not harm Nature. Waste from all the enterprises in the region is delivered to the receptors of the reactor. Here, pipelines would probably do best, but one could, of course, also do with the conventional transport facilities and deliver the waste by railway or truck.

"In the receptors, the solid waste is crushed and the dust-and-gas mixture thus obtained is moistened. A special device constantly controls the make-up of the incoming 'raw material' and issues signals whenever necessary for enriching it with the required additives. From the chambers, the mass goes up vertical shafts to the main collector. In the time it takes the mass to move to the collector, all the chemical reactions in it must be completed. When these

are completed, the gas phase is removed via the gas outlet, while the solid and liquid phases in the form of pulp are pumped into sumps, where the solid is separated from the liquid.

"The gas is purified of dust and aggressive components and piped to hot-houses where plants absorb the carbonic acid. At the same time, the gases are saturated with oxigen. The gas mixture so obtained is controlled and brought up to the standards of pure air. Only then are the gases emitted into the atmosphere.

"The finely dispersed solid phase is enriched with organic fertilizers, is left to lie in beds and then taken out into the fields.

"The combine will evidently not produce any liquid substances, because the water entering the reaction in the form of industrial effluent will be required to moisten the air and will be emitted together with it into the atmosphere in the form of steam. If the industrial effluents are not adequate to the purpose, the combine will have to be supplied with water.

"Members of the laboratory have estimated the establishment of such a combine will naturally require large expenditures, and we have already made preliminary estimates of the cost.

"Such a combine will cost about 200 million rubles to build—a lot of money, of course. But one should bear in mind the other side of the matter, namely, the damage being done by the absence of a complex solution of ecological problems.

"Calculations showed that the outlays on the construction of a resources combine in Zaporozhye could be recouped within five years, and that from then on it would yield a sizable profit."

Nagorny has summed up the experiment in Zaporozhye as follows: "The work that has been done at our laboratory has not only mapped the ways but has also brought out the serious difficulties in going over from the resource-extractive method of economic activity to the resource-recycling method. The construction of a stable, Man—Nature equilibrium system is being impeded not only by the mentality of the primitive collector of the fruits of Nature, which we have inherited from the hoary past, but also by the existing organisation of production.

"But we are sure that man's mature reason will be able to rise over and above the here-and-now and local interests for the sake of mankind's immediate and long-term interests, and to act in such a way as to leave behind him forever the pessimistic picture suggested by the poet's imagination:

'There is less and less surrounding Nature,
There is more and more environment'.

"The laboratory at Zaporozhye is making a contribution to the tremendous and diverse work which is being carried on in the USSR in the economical and thrifty use of natural resources. We seek to have scientific and technical progress go hand in hand with care of Nature and its wealth, so providing the most favourable conditions for human life."

Such is the highly optimistic attitude taken by Soviet scientists and such are some of their practical efforts in this important field.

The effort to combat soil errosion and the pollution of air and water are large-scale and require appropriate material and financial inputs.

In 1973 alone, 1,700 purification complexes processing over 13 million cub. m. of water a day were started, hundreds of dust-catchers have been built, and forests renewed on a territory of over 1 million hectares.

The results of these purposeful efforts to protect Nature have already begun to tell. For instance, over the past few years pollution of the Caspian Sea with petroleum has been markedly reduced.

In the USSR, highly promising work in bio-economic projection is being carried on. This means the complex planning of large-scale economic system, taking into account their extensive ties with the environment.

There is a special effort to protect Lake Baikal, a unique body of water. The CPSU Central Committee and the USSR Council of Ministers passed a special resolution to ensure the rational use and preservation of its natural resources. Much has already been done. Dozens of local purification installations have already been built. The drifting of timber along all the rivers emptying into Lake Baikal has been stopped, and their beds are being cleared of deadwood. A project has been approved for setting up a water conservancy zone on the lake.

The dialectics of the phenomenon we have been considering consists in the fact that *while environmental problems spring from rapid industrial development under the impact of technical progress, the latter itself provides the material facilities for tackling these problems.* The achievements of science and technology make it possible to find and put through effective measures for the protection of Nature.

Thus, solution of environmental protection problems is largely related to the new technological methods, to the *complex use of natural resources.* The underground leaching of copper ores in hydrometallurgy, notably with the use of bacteria, not only accelerates the process of production many times over, but also excludes any emission of noxious gases into the atmosphere. The use of progressive closed-cycle method based on the principle of the compex use of basic raw and other materials does not produce any waste and reduces the volume of natural-resource inputs.

At the old oil-refineries, the expenditure of fresh water per ton of refined oil is very high (for instance, at the Novo-Yaroslavsky plant, which was designed in 1959, it came to 7.97 cub. m. which resulted in sizable effluents), but the Mosyr refinery in Byelorussia (designed in 1967) provides for the expenditure for 0.84 cub. m. of water, and the Aginsk refinery in Chita Region for 0.12 cub. m.; the project for the Vinnitsa refinery in the Ukraine provides for the complete exclusion of any industrial effluents, which means that it will have a totally closed cycle.

The rational use of forest resources is of great importance, for it bears on the complex use of natural resources, the level at which forest resources are reproduced, the extent to which timber waste is used, and finally, the extent to which the forests themselves perform their functions of key component of the ecological equilibrium (preservation of the air and protection of the soil and water).

An extensive complex of problems relates to *the protection of soils and land resources generally.* Even in the USSR, which has a vast territory, land, especially farmland, tends to become a scarce resource. This is due above all to the fact that a comparatively small part of the country's territory lies in the zone with favourable temperatures and adequate precipitation (over 700 mm). Let us

note that nearly one-half of the US territory lies in such a zone.

The STR opens up fresh potentialities for the protection of land resources. There is above all *the use of chemicals in agriculture*, notably adequate quantities of complex and effective fertilizers. Soviet industry has been rapidly increasing their output.

The 25th Congress of the CPSU broadly considered the problems of environmental protection. Its Guidelines for the USSR's Economic Development from 1976 to 1980 say: "*To work out and put into effect measures for environmental protection and for a rational utilisation and reproduction of natural resources*"[1].

These tasks were also extensively dealt with by the 26th Congress of the CPSU. The Guidelines for the Economic and Social Development of the USSR for 1981-1985 and the Period up to 1990 say:

"To improve the standards of environmental protection, make a harder effort to preserve the farmland, . . . to promote a more comprehensive exploitation of mineral deposits, . . . to improve the state control over nature utilisation and protection of the environment."

Although each country has its own ecological problems, intactness of the biosphere is by its very nature an international problem. This is exemplified by the ocean. Here is what the famous traveller and scientist Thor Heyerdahl says in this context:

"Strictly speaking, there are no 'national waters' in the ocean. The ocean is in perpetual motion. It is possible to map out and share out between the states the immobile bed of the sea but not the waters above it. If you launch a raft off the coast of Peru, within a few weeks the currents will have carried it to Polynesia. If you board a reed boat on the coast of Morocco, after a while you will find yourself in Tropical America. That which is today called the territorial waters of Peru, tomorrow becomes the territorial waters of French Oceania. The off-shore waters of Morocco become the waters of the Gulf of Mexico.

"It is highly important to put an end right away to the deliberate dumping of waste into the ocean. But that is only

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[1] *Documents and Resolutions. XXVth Congress of the CPSU*, p. 6.

a part of the problem, because immensely more poisonous waste constantly reaches the sea along the streams and rivers, from the sewerage systems and industrial effluents.

"Because the ocean does not overflow its shores, despite the fact that all the rivers of the world constantly fill it with water, we tend unconsciously to regard it as some kind of charmed boiler which will never brim over no matter how much you pour into it. We tend to forget that the role of drain in the ocean is played by evaporation from its surface. And it is pure water that is evaporated, while the poisons and other waste remain. How much solid and liquid waste is accumulated each minute? Let us imagine the ocean without water—a vast dry hole with man-made waste alone oozing in. We will see rapid streams rushing into the hole on every side and filling it before our very eyes. Let us take a number of casual examples.

"Every year the rivers of France carry into the ocean 18 million cub. m. of liquid effluents; Paris alone daily disgorges into the Seine nearly 1.2 million cub.m. of unpurified drainage waters.

"In the FRG, liquid effluents come to over 9 billion cub. m. a year, i.e., 25.4 million cub.m. a day. Add to this the daily expenditure of 33.6 million cub.m. of water for cooling. Fifty thousand tons mainly of industrial effluents are dumped into the Rhine alone every day."[1]

Heyerdahl goes on to cite other convincing examples connected with the world ocean, which show that ecological problems are international. "The fat of 20 whales recently caught for research purposes off the coast of Eastern Greenland contained traces of six poisonous chemicals, including DDT. These whales were born and grew up by the glaciers of Greenland, and had never approached the coasts of agricultural areas. But ocean currents run along distant routes, and carry with them the pelagic plankton, which is consumed by krill, the whales' staple food. Like oil, plankton has the capacity to absorb, assimilate and concentrate insecticides. The ubiquitous micro-organisms filter off food for themselves from the sea water, consuming not only nutrients but also the noxious chlorinated hydrocarbon. The

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[1] *Nauka i zhizn*, No. 7, 1978, pp. 88-89.

poisons absorbed by the plankton then pass into the tissue of fish and eventually into the tissue of man. Plankton itself hardly moves, while fuel oil and pesticides cannot swim at all, but the problem of their transportation is solved by wind, river and ocean. Thus, one type of DDT used on the fields of East Africa was discovered in the waters of the Bay of Bengal within a few months."[1]

Heyerdahl's call is important and well-grounded. "I urge abandonment of the short-sighted personal and national yardsticks and an effort to realise the tremendous responsibility falling on the present and coming generations. Marine currents do not reckon with political boundaries. States may share out land among themselves, but the ocean, the restless ocean, without which life is impossible, will always be the common and indivisible asset of the whole of mankind."[2]

There is a need for world-wide cooperation to safeguard the globe for human beings. The Soviet Union's struggle for detente and for deepening peaceful co-existence is a most important contribution to the efforts to safeguard our biosphere.

Such are some of the problems in protecting natural resources and using and safeguarding them in the interests of the present and coming generations. Socialism opens up the most favourable potentialities for solving this cardinal problem facing mankind today.

7. SCIENTIFIC AND TECHNICAL PROGRESS IN TRANSPORT AND COMMUNICATIONS

Transport and communications are key component parts of morden production and are vitally necessary for the normal functioning of society. *The role and importance of transport and communications are steadily enhanced with the progress of material production and the closely related advance of human civilisation.*

Society's requirements in transport and communications have reached gigantic proportions, and these have been growing at a very fast pace. Over 41 billion tons of freight

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[1] *Ibid.*
[2] *Ibid.*

and over 38 billion passengers were carried by all types of transport in the USSR in 1977 alone. These are truly huge proportions! Since the war, the carriage of freight has multiplied 16.6-fold, and of passengers—21-fold.[1]

The data below show the vast scale on which state communications in the USSR now operate.[2]

	1940	1974
Communication products (bln rubles)	0.6	4.5
Letters, newspapers, magazines, parcels and postal orders (mln)	9,422	49,280
Cables (mln)	141	421
Long distance telephone calls (mln)	92	684

It is perfectly obvious that this tremendous volume and high rate of growth would have been impossible without a radical technical re-equipment of transport and communications, without the impact of the STR. At the same time, the revolution in the means of transport and communications itself exerts a powerful influence both on material production and on the production of spiritual values, on every aspect of the intellectual and spiritual life of the individual and society as a whole.

In the Soviet Union, great importance is attached to realising the potentialities of the STR in the development of transport and communications because of its vast territory, the intensive working of new natural resources in remote areas, the need for the rapid and complex development of these areas, and other factors.

What are the processes determining the growing requirements in transport and communications, and what are the STR processes in these fields?

The development of material production and the closely related progress in the division of labour on the national and international scale have tended to complexify spatial and time connections at all the hierarchical levels of social production. Scientific and technical progress and the ever

[1] See *Narodnoye Khozyaistvo SSSR v 1977 g.*, pp. 150, 151, and also *Narodnoye Khozyaistvo SSSR za 60 let*, pp. 395, 402.

[2] *Ibid.*, pp. 152, 153.

more complex nature of products and, accordingly, the process of production, create the most involved space-and-time connections both within production enterprises and between various enterprises, and require the establishment and development of an adequate system of communications. An idea of the scale of intra-plant transport operations will be gained from the fact that freight turnover on spur tracks is almost thrice the freight turnover on all the railways of the USSR.

We find similar processes in human relations which are not immediately connected with social production. The years and stages of education and training, the extensive network of establishments in culture, tourist travel, sport, medical and health-improvement establishments, together with the steady spread of urbanisation, all of these multiply and complexify the ties between people. At the same time, there is a growth in the volume and range of requirements in information—general knowledge, special, scientific, professional and cultural—and information simply about various events going on in the country and all over the world. All of this determines the growing requirements in every type of communications.

The transport and information facilities which have existed over a relatively long period evidently run into contradiction with the increased production, social and individual requirements. The logic underlying the development of human society has insistently demanded revolutionary changes in the means of transport and communications, and their content has been as follows:

First, *a vast increase in speeds and load-carrying capacity in every type of traditional transport.*

> The steam-engine, which came on the scene in 1825, had a maximum speed of 21 km. per hour. Today, trains often run at 200-300 km. per hour. In the 1980s, they could well reach the speed of 400 km. per hour. Gas turbines will be extensively used as transport engines. Trains moving in a closed tube (tunnel) are now at the engineering stage. Passenger cars in the form of capsules the size of the fuselage of a modern aircraft could well develop speeds of up to 800 km. per hour. Such experimental pneumatic cars are already used to carry freight at the Batelle Institute in Geneva.

The steady increase in the h.p. rating of locomotives, especially with the switch of railway transport to diesel and electric traction, has sharply increased the load-carrying capacity of railway trains, to 2,000-3,000 and more tons. Scientific and technical progress in ship-building and the equipment of ships with ever more powerful engines make it possible sharply to increase the tonnage of ships. For some years now, tankers of 500,000 tons and over have been used on commercial runs. There is real prospect for the use of 1 mln tons atomic-driven freighters.

The steady growth of the load-carrying capacity of road transport, notably the development of truck-trains, with a multiplication of the speed, has turned automobile transport into a powerful rival of railway transport, and has also produced highly efficient forms for combining rail and railless transport.

Second, *pipeline transport, a new type of transport, has emerged and is developing faster than the other types*, for it takes on an ever larger and prevailing share of the liquid freight and almost the whole of gaseous freight. Some countries now operate pipelines for friable materials like coal.

Third, *there has been exceptional growth in the load-carrying capacity and speed of air transport.* During the Second World War, aircraft already had speeds of over 600 km. per hour. Within 25 years, the speed doubled, and by the end of the 1960s, jet planes flew faster than the speed of sound. In the USSR and Western Europe, supersonic passenger jets—the TU-144 and Concord—are already in use. Further revolutionary changes in the speed of transport vehicles are already being effected in space flight: spaceships orbit the Earth at 29,000 km. per hour.

Fourth, *the technical basis has been created for bridging the gap between various conjugate types of transport.*

The STR lines in the field of transport are of tremendous economic and social importance, opening up once inconceivable potentialities for specialising production and eliminating many constraints in locating it. Progress in industrial transport facilities has created the prerequisites for a marked intensification of production. The mobility of the whole of social production tends sharply to increase.

One could say that two great technical discoveries—the car and the plane—which were made in the 20th century have changed not only facilities and speeds in transportation but the very mode of human life. The well-known English scientist Arthur Clarke says that "the automobile and the airplane have created a world that no man a hundred years ago could have conceived in his wildest dreams".[1] They have enabled society to make a great leap forward in mastering space and time, relatively small distances (the car) and great distances (the plane) and small and large intervals of time. Millions of people daily move across the globe by plane, car, train and ship, and can reach virtually any point on the globe within 24 hours. This factor has radically changed the whole of mankind's way of life.

Even more revolutionary changes are taking place in the means of communication. The basis for these has been provided by light currents and electronics. Radio and television enable people to overcome distances and have made the remotest areas of countries and the whole world accessible to various information, as will be seen from Intervision broadcasts. The potentialities for training and raising skill standards have immensely increased. New means of communication, together with new information hardware—computers—help man to handle immensely larger volumes of information. Future "data banks" will be generally accessible like any public library, with the difference that subscribers will not have to leave their homes to use them.

New communication technology is having an equally radical impact on production and its organisation. Selector, telephone, radio and industrial TV have revolutionised all production communications: within the shop, within the plant, between plants and between industries. Production at every level is now controlled at once inconceivable speeds, with a swift and rapid visual presentation of its processes.

The new communications technology is a tremendous factor in boosting the productivity of labour. Production and, in a sense, the whole of social life would be paralysed if telephone, radio and TV were to be shut down for one day.

One should bear in mind that the services being provided by communications on a massive scale today are only the

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[1] Arthur C. Clarke, *Profiles of the Future*, New York and Evanston, 1966, p. 37.

initial stage in the realisation of their present potentialities. Orbiting Earth satellites are already being used for mass broadcasts. By the end of the 1980s, video-telephone and other types of video communications will evidently be in wide use. Visual communications help to solve a number of problems. They transmit pictures of texts, diagrams, blueprints, persons and any other object. They make it possible to effect remote control of computers and other machines, and enable doctors to diagnose their patients who may be on the opposite side of the globe. In some instances, the new potentialities of communications produce essentially important alternatives to transport. Over the long term, the development of video communications and the introduction of holography will further increase the possibilities of communication over long distances and are sure to offer some competition to passenger transport.

Such are just a few important characteristics of the process of the present-day STR in the field of transport and communications.

In close connection with these processes, there are already *important structural changes in transport and accordingly, in the economy of developed countries.*

This will be seen from the data on the changing structure of freight carriage in the USSR.[1]

> In 27 years, freight turnover multiplied 7.9-fold, and passenger travel, roughly 8.2-fold, while air freight multiplied 20-fold, and passenger flights—106-fold; road freight 19-fold, and passenger road carriage—66-fold. Marine freight has also grown at a faster rate (19.2-fold) and pipeline transport (168-fold).

The accelerated growth of pipeline, air and road transport is a characteristic feature of the changing structure of transport in the USSR.

> Accordingly, over the same period, the share of railways in freight turnover dropped from 84 per cent to 59 per cent, and in passenger carriage from 90 per cent to 40 per cent. Meanwhile, the share of road and air transport in passenger carriage went up from 6.5 per cent to 58.8 per cent, or more than 9 times.

[1] See *Narodnoye Khozyaistvo SSSR v 1973*, pp. 499, 500; *Narodnoye Khozyaistvo SSSR v 1974*, pp. 471, 472.

Railways are faced with an important and difficult struggle for their "place in the sun", especially in passenger carriage. This was well described by Najib E. Halaby, Senior Vice-President of Pan American World Airways, who says: "In terms of people transportation, the railroad is today an evolutionary misfit. It is a brontosaurus fighting for survival in a world of jackrabbits and swallows. From the day its tracks are laid, the railroad fights its inherent mechanical inefficiency—its need for tons of rolling stock to carry pounds of passengers, a cumbersome economics, and what might be called a social inflexibility. As a bulk-freight carrier... the railroad suffers from its own built-in deficiencies, for it is a short-armed giant that often cannot quite reach either the producer or the consumer of the goods it carries."[1]

While this may sound paradoxical, it is quite logical. However, one will note that Halaby does not suggest the elimination of railways, although in the United States, with its vast network of freeways, some railway lines are in cold storage.

Rational combination of every type of transport is the main line, as will be seen from the development of the transport system in the USSR. Despite the marked reduction in the share of railway transport, its share in the overall freight turnover in 1977 came to over 59 per cent. It will maintain its leading position for the carriage of heavy loads over great distances now and in the foreseeable future. This is determined not only by the prevalence of railway transport but also by the fact that it is still the cheapest type of transport.

In 1975, 10 ton/km cost 2.48 kopeks by rail, as compared with 2.59 kopeks by river and 50.5 kopeks by road. Marine transport is the cheapest of all—1.98 kopeks—but within the country these types of transport are virtually not interchangeable at all.

The difference in the cost of passenger carriage is smaller, but is also in favour of the railways. In 1975, it came to 6.06 kopeks for 10 pass/km by rail, 10.64 kopeks by road, and 17.53 kopeks by river.

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[1] See N. E. Halaby, "Transportation", in *Toward the Year 2018*, 1968, New York, p. 38.

The task of developing Siberia and the Far East, and the Northern areas of the country requires the construction of new railway lines which are sure to be the main arteries for the economic development of these areas over the immediate future. Tremendous economic importance attaches and will continue to attach to the already functioning Central Siberian Railway, the Tumen—Tobolsk—Surgut Line, the Baikal-Amur Railway, which is under construction, etc.

Considering that railway transport will maintain its leading positions for some time to come, technical policy is based on a combination of accelerated development of pipeline, road and air transport, with intensive technical re-equipment of railway transport.

> This will be seen from the following data for 1950-1977. The share of electrified and diesel-traction lines increased from 5.3 per cent to 97 per cent of rail freight turnover, while the share of steam-traction dropped from 94.6 per cent to 0.1 per cent.

Virtually the whole of railway transport has been switched to the most progressive type of traction: electrical and diesel. Reconstruction on such a scale was made possible only because of the major advances in electrification. The consumption of electricity by transport increased from 3.7 billion kwh in 1950 to 82.7 billion in 1976.

These major technical changes in transport not only made for considerable structural changes but also produced a number of complex problems.

The first and the most complicated of these is *to make transport processes continuous*, especially at the conjunction of the various types, and to make them more rhythmical.

Equally difficult problems spring from the rapid development of road transport. Above we noted the threat posed to the environment by the millions upon millions of automobiles. Besides, automobile transport requires tremendous inputs of social labour into the construction of highways. This is an especially important problem for the USSR, considering the size of its territory and the relatively inadequate length of its highways with improved surfacing. The solution of this problem is connected with some new trends in technical progress in the field of transport.

Just now *there is evidence of a most pronounced emergence of the contours of a new technical revolution in transport*,

which could prove to be as radical an advance as the emergence of the car and the plane. I mean the emergence of air-cushion transport (hovercraft) whose spread could well oust the use of the wheel in the field of transport.

> The effort to produce wheel-less transport vehicles has a fairly long history. Back in 1927, Konstantin Tsiolkovsky published a book in Kaluga entitled *Air Resistance and the Fast Train*, in which he gave the first constraints and assessments of the energy inputs for an aerotrain. In 1934, the first air-cushion vehicle was developed and tested under the direction of Professor V. Levkov of the Novo-Cherkassk Polytechnical Institute. In 1961, the design was started in Britain of road platforms for "Hovercars". In 1966, the French Aerotrain-01 developed a speed of 200 km. per hour on a trial run over a road 6.7 km. long, and in 1968, Aerotrain-02 developed a maximum speed of 378 km. per hour. In 1969, the US Department of Transport signed contracts with a number of corporations to design an aerotrain with a speed of 500 km. per hour.

Air-cushion transport has great advantages among the other types of wheel-less ground transport, because it is not only more efficient but offers a radical solution for the problem of roads. All it needs is transport strips cleared of obstacles. There is no need for any solid supports, because the weight of such vehicles is spread over an area of several square metres and is not concentrated at individual points of contact with the ground. Japanese specialists have estimated that hoverbuses will already be in use by 1982.

Air-cushion vehicles open up great possibilities before river and marine transport. Let us note that hovercraft knows no boundaries between land and sea, so that there are no loading and unloading problems. There is also no need to build great harbours and ports.

Arthur Clarke, a great enthusiast of hovercraft, says in the book quoted above: "With the emancipation of traffic from the road, we will at last have achieved real mobility over face of the Earth... Pampas, steppes, veldt, prairies, snowfields, swamps, deserts—all will be able to carry heavy, high-speed traffic more smoothly, and perhaps more economically, than the finest roads that exist today... Yet both

(the automobile and the airplane—*S. H.*) are now being challenged by something so new that it does not even have a name—something that may make the future as strange and alien to us as our world of super-highways and giant airports would be to a man from 1890."[1]

Those are some of the potentialities which the STR has opened up—and continues to open up—before transport and communications, converting this sphere into an ever more powerful factor in the development of the productive forces and exerting an influence on human life and men's physical and intellectual potentialities.

8. THE STR AND SPACE EXPLORATION

Space exploration is a field where the Soviet Union has scored great successes in science and technology. Let us recall that these epoch-making achievements were made by the Soviet Union: the orbiting of the first artificial satellite of the Earth, man's first flight in space, man's first exit into outer space, the longest stay in outer space, and flights by spaceships to stations in outer space. The Russian scientists N. Kibalchich and K. Tsiolkovsky had an outstanding role to play in working out the theory of jet-propulsion and the theory of space flight.

Present-day space exploration is undoubtedly the crowning achievement of the STR, epitomising and materialising all its achievements. At the same time, space exploration is an exceptionally powerful catalyst in the further progress in science, technology and production.

Ballistic rockets and fantastically powerful boosters, metals and alloys with unparalleled properties, synthetic fuels of unheard-of concentration and heat-value, automatic, telemechanic and electronic information devices, unique radio and TV communications, and self-sufficient and closed-technology systems never before seen in the history of technical development—those are only some of the things that have already been achieved in the process of space exploration.

The development of cosmonautics exerts a marked influence on overall scientific and technical progress and the

[1] Arthur C. Clarke, *Profiles of the Future*, pp. 37, 41, 42.

intensive development of many fields of applied sciences and technology. In this context, Academician M. V. Keldysh wrote: "In the view of the requirements of space technology, there has been a development of dozens of new types of metallic and non-metallic structural materials, strongly welded alloys based on titanium, nickel, copper, molybdenum and aluminium, special high-quality steels, non-combustible, heat-resistant, acid-resistant and anti-corrosion materials and coatings, non-gas high-temperature electric insulation materials, and pressurising packers, various lubricants, inorganic dyes and varnish-and-paint coatings. New types of highly efficient sources and transformers of electric power have been developed. The chemistry of fuels and the theory of combustion have made great advances".[1]

Exceptional influence is exerted by the very rigid demands which cosmonautics makes on the size and weight of all hardware used in space exploration. It stimulates microminiaturisation in electronics, the fabrication of minicomputers, etc. All of this should naturally promote overall progress in every field of technology and production.

The prospects before space exploration suggest new and ever more complex tasks. A promising line is the exploration of the planets by means of automatons of the next generation with a high degree of autonomy in movement along surfaces, a capacity to perceive the environment, to analyse it and to take decisions on subsequent action, depending on the situation. The development of such automatic devices entails the solution of problems now designated by the concept of "artificial brain" and "integral robots".

Space exploration has already yielded great returns for the economy. The Directives of the 24th Congress of the CPSU for the Ninth Five-Year Plan period envisaged "research in outer space for the purpose of further developing telephone and telegraph communications, television, meteorological forecasting, and the study of natural resources, geographical exploration and the carrying out of other national-economic tasks with the aid of satellites, automated and manned craft, and continuation of fundamental scientific studies of the Moon and the planets of the solar system".[2]

[1] *Nauka i zhizn*, No. 4, 1974.
[2] *24th Congress of the CPSU*, p. 251.

This great but very practical complex of problems is being tackled from day to day. Already space communications facilities have an important role to play in the Soviet people's life, providing practical services for the population in Siberia and the Far East. Artificial satellites of the Earth, moving along high orbits and equipped with relay facilities, receive signals from ground stations and, after duly amplifying them, return them to the Earth, where they are received by stations thousands of kilometres away from the transmitting stations. Communications satellites relay television programmes and provide telephone and telegraph communications.

There is ever more extensive use of satellites for marine and air navigation. Satellites with highly precise orbits transmit their coordinates to ships and planes which enable them to determine their own coordinates by establishing their position relative to the navigation satellites.

Thus, Cosmos-1000, launched in the USSR in 1978, has the task of ensuring navigation at sea. Yuri Kravtsov, technical chief of the atomic ice-breaker *Sibir*, says that "the navigator-satellite is designed for the needs of the present expedition. It is necessary that the caravans which will follow the *Sibir* and the *Kapitan Myshevsky* into the Arctic should have the most precise idea of our course. And satellites alone can provide the surest course for these ships."[1]

Multi-zonal photographic facilities on board the orbital station *Salyut-4* enabled cosmonauts A. Gubarev, G. Grechko, P. Klimuk and V. Sevastyanov to photograph large areas of the south of the USSR, so providing information for over 300 organisations and establishments, including 150 research institutes, 166 design and exploration institutes, and 26 higher schools.[2]

For a number of years now, a system of weather satellites has had an important part in providing global meteorological data, giving greater precision to weather forecasts and predicting natural calamities.

Satellites helped to work out maps, showing the distribution of clouds, the heat radiation of the Earth and the movement of cyclones. These data are constantly transmitted to world meteorological centres. The use of spaceships has

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[1] *Izvestia*, May 29, 1978.
[2] See *Izvestia*, February 28, 1978.

already helped to discover mineral deposits, and weather data are used for agricultural and other purposes.

Space technology could play an important role in the global planetary control of the state of the environment and its protection. Photographs of the Earth's surface taken through various light filters and by means of other methods show the distribution of vegetation, changes in the blanket of snow, the overflowing of rivers, and the state of crops and forests, and help to assess expected crop yields and to discover forest fires.

Satellites also make it possible to carry on oceanological and hydrological research. They are valuable in geodesy and topography for the purposes of precisely tying in points far away from each other, and rapidly bringing topographic maps up to date.

Space exploration also has an important cognitive role, for it broadens man's horizons and increases the potentialities of the basic sciences in gaining a knowledge of the fundamentals of the Universe.

Space technology makes it possible to take the most sophisticated measuring instruments to once inaccessible areas in inter-planetary space and also to other celestial bodies. This releases science from the constraints imposed by the Earth's atmosphere, and, according to Keldysh, ensures a "global reach in studying processes and phenomena going forward on the Earth and in its environs". Realisation of these potentialities produce great advances in all the basic sciences, including astronomy, elementary-particle physics, the study of nuclear processes under super-high energies, areas which will remain inaccessible to the largest accelerator down here for years to come.

Outer space can also be used to carry out some very fine technological processes. Soviet cosmonauts have done welding work in outer space vacuum. Satellites can carry the necessary technological installations, while transport space vehicles, like *Progress*, which have already delivered freight to an orbital station, could deliver raw materials and return the finished product to the Earth. Cosmonautics may well enable mankind to assimilate the material and energy resources of the Universe.

Finally, the global nature of space exploration largely promotes international scientific and technical cooperation, as exemplified by the *Soyuz-Apollo* space flight, an impor-

tant contribution to bringing the peoples of the world closer together and easing international tensions.

The 25th Congress of the CPSU set the task of further developing space exploration: "To carry on space research and utilisation, to extend research on the application of space means in studying the Earth's natural resources, in meteorology, oceanology, navigation, communications and other economic uses."[1]

9. THE STR AND THE NON-PRODUCTION SPHERE

The production of services and the dissemination of knowledge and spiritual values have an ever more important role to play in attaining the supreme goal of social production under socialism: the fullest possible satisfaction of men's material and cultural requirements. This sphere includes housing with the whole complex of communal services and utilities, public transport, including the roads, retail trade and public catering,[2] establishments providing diverse everyday services, public health and sports, education and culture.

Contrary to earlier notions that with progressive automation the role of human beings in the process of production allegedly tends to be reduced, experience has shown that the development of social production under the STR makes steadily growing demands on the skills, educational, intellectual and spiritual development of the members of society.

Man is the subject and creator of scientific and technical progress, and the director and organiser of material production. Consequently, the steady development and enhancement of man's creative, intellectual and spiritual potentialities is a most important prerequisite for the further advance of civilisation. The accumulation of knowledge and its transmission to coming generations is the basis for the progress of science, technology and production. That is why the *utmost and priority development of the sphere of dissemination of knowledge, the reproduction and the physical and spiritual*

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[1] *Documents and Resolutions. XXVth Congress of the CPSU*, p. 234.

[2] In accordance with the methodology accepted in the USSR, retail trade and public catering are included in material production.

improvement of man are a key uniformity in the development of the socialist society.

The basic task of the whole process of socialist construction is the shaping and development of economic, social and psychological conditions for creating the most progressive and highly developed productive forces, and for a revolutionary change in the very basis of civilisation as the foundation of human life. That is why society's chief goal is the all-round development and the fullest satisfaction of man's growing material, intellectual and spiritual requirements.

This idea was clearly formulated in the report of the CPSU Central Committee delivered at the 24th Congress by Leonid Brezhnev: "The Party also proceeds from the fact that a higher standard of living is becoming an ever more imperative requirement of our economic development, one of the important economic preconditions for the rapid growth of production.

"This approach follows not only from our policy of further accentuating the role of material and moral incentives. The question is posed much more broadly: to create conditions favourable for the all-round development of the abilities and creative activity of Soviet people, of all working people, that is, to develop the main productive force of society."[1]

The socialist state in the USSR works to realise in practice the policy of all-round development of the sphere of the services for the Soviet people's material and everyday requirements and the development of society's spiritual potential.

As a result of sizable capital investments, fixed assets in this sphere have grown markedly, and by the end of 1977 came to 504 billion rubles (in comparable 1973 prices), a 22.8-fold increase over the pre-revolutionary period.

Prevalent among these assets are housing facilities (valued at 294 billion rubles on January 1, 1978). In the public utilities and everyday services, fixed assets came to 64 billion rubles, in public health and educa-

[1] *24th Congress of the CPSU*, p. 51.

tion to 86 billion, and in science, culture, art and other non-production sectors to 60 billion rubles.

In the USSR, the volume of housing construction is vast. In the period between 1950 and 1977, 2.48 billion sq. m. of general housing space was built, three times more than the figure for all the preceding years of socialist construction. Trade, public catering, education, public health and other areas have been developed on the same sweeping scale.

The growth of the intellectual potential is characterised by the scale on which education and science are developed. In the 1977/78 academic year, a total of 58.8 million persons were enrolled in the network of academic establishments, including 5 million in higher schools. At the end of 1977, Soviet scientific establishments, including higher schools, had 1,262,000 scientific workers, or a quarter of the number in the world. The USSR has a ramified network of technical, research and development institutes.

Behind these figures is a tremendous effort to shape an extensive complex of sectors catering for the reproduction of man, society's prime productive force. In the socialist society, with the progress of the productive forces and the people's growing wellbeing and educational and cultural standards, social and non-material requirements increasingly come to the fore.

These structural changes are reflected in the structure of enterprises in the service sector. The number of those working in the arts increased from 185,000 in 1950 to 450,000 in 1977. The number of persons employed in the sphere of culture went up from 556,000 in 1965 to 1,150,000 in 1977.

The provision of services and spiritual values is a sphere that has developed in accordance with the same dialectics of the relations between the STR and social production.

The current STR exerts a revolutionising influence on the non-production sphere and everyday life.

The following data show the growing manufacture of technical appliances and facilities and their use in Soviet homes.

Articles (ths)	Production				Per 100 families	
	1950	1960	1970	1977	1965	1977
Watches and clocks	7.6	26	40.2	6,0.3	319	486
Radios and radiograms	1,072	4,165	7,815	8,652	59	83
TV sets	11.9	1,726	6,682	7,069	24	79
Tape recorders	—	128	1,192	2,592	—	—
Refrigerators	1.2	529	4,140	5,802	11	73
Washing machines	0.3	895	5,243	3,648	21	69
Vacuum cleaners	6.1	501	1,509	2,749	7	22
Cameras	261	1,764	2,045	3,582	24	28
Motocycles and scooters	123	533	833	1,089	6	9
Bicycles and motorbikes	649	2,783	4,443	5,228	48	52

In the quarter-century, the manufacture of the most modern appliances reached tremendous proportions: radios and radiograms—8.7 million, TV sets—7.1 million, tape-recorders—2.6 million, refrigerators—5.8 million, washing-machines—3.6 million, vacuum cleaners—2.7 million, etc. From 1975 to 1977, over 1 million cars were sold in the USSR every year.

Commercial automatic machines are being ever more extensively used everywhere.

Automatic electronic data processing facilities and inter-urban information communications are being broadly introduced into the non-production sphere.

Electronic computers are being increasingly used for instruction.

The results of experiments involving the use of computers at school have helped to determine the mathematical abilities of children. These machines exercise their functions individually. As soon as the pupil has printed their name and personal number, they locate his card and present it for the solution of problems specially written for him in the light of his past achievements and personal abilities to assimilate new material. Teachers are given daily progress

reports on the work done, with a listing of the performances of each pupil, and periodically more elaborate reports which do away with superfluous paper-work. If the teacher gets the impression that a pupil requires special attention, he is able to obtain all the necessary information about him.

There is now in evidence a process of transition to programmed instruction with the use of electronic facilities and audio-visual aids.

Medical establishments are being increasingly equipped with modern diagnostic, medicinal and control-and-measuring devices.

> Electronic computers at hospitals analyse electrocardiograms and other objective indicators, monitoring the state of patients, constantly measuring their heart and breathing functions, temperature and blood pressure.

There are two aspects to the importance of the problems in the technical re-equipment of the non-production sector.

The first is that the state of work in this field determines the satisfaction of man's intellectual and spiritual requirements, helps to convert non-working time into real leisure, and provides the opportunities for using it to enhance the spiritual potential of every member of society. The potentialities of the STR should evidently be used to the utmost for these purposes.

The second aspect is that the service and cultural sphere tends to involve the work of tens of millions of men and women even today, when it still falls far short of satisfying society's requirements.

> In 1977, 4.0 million people were employed in the housing and public utilities sector and everyday services, 6.9 million in retail trade and public catering, 6.0 million in public health, physical training and social security, 10.1 million in education, culture and art, 4.0 million in science and scientific services, a total of 31 million men and women.

The problem of labour productivity of this crowd of more than 30 million is of exceptional importance. Technical equipment and re-equipment of this whole sphere should

release millions of men and women from routine operations and enable them to perform ever more creative functions, i.e., to ensure the utmost economy of inputs of living labour as it becomes much more productive and efficient. At the same time, this will make it possible considerably to increase the volume and raise the quality of services offered to the population. In present-day conditions, with the growth of wellbeing, the share of inputs into cultural and everyday needs tends to grow. From 1940 to 1976, this share in the budget of Soviet industrial-worker families increased from 17.5 per cent to 22.4 per cent, and in the budgets of collective-farm families from 4.4 per cent to 15.2 per cent.

Those are some of the problems in realising the potentialities of the current STR in the non-production sphere.

CHAPTER FIVE

WAYS OF REALISING THE POTENTIALITIES OF THE STR IN COMMUNIST CONSTRUCTION IN THE USSR

1. A TASK OF HISTORIC IMPORTANCE

The tremendous potentialities of the STR are not realised automatically. Scientific and technical progress does not always move smoothly, rapidly or without any hitch from the discovery in the basic and applied sciences to the engineering of the new technology. A time gap (frequently quite a large one) tends to exist between the successive stages of this advance and within each, and all of this slows down the realisation and reduces the efficiency of scientific and technical progress and social production as a whole.

The ever more extensive application of scientific and technical achievements in social production and the marked increase in the cost of research, development and engineering projects pose the very acute problem of the effectiveness of scientific and technical progress and insistently demand the elaboration and implementation of a system of measures ensuring its enhancement.

The coexistence of new and traditional machinery confronts society with the need to harmonise high rates of scientific and technical progress with the fullest and most efficient use of the available means of production.

The socialist society tackles these and many other problems relating to scientific and technical progress in the light of the scientifically formulated economic policy of the Party and the socialist state, itself a powerful factor in scientific and technical progress.

This is a quest for ways to fulfil the historically important task formulated by the 24th Congress of the CPSU, namely, "*organically to fuse the achievements of the scientific and technical revolution with the advantages of the socialist economic system*".[1] The solution of this problem is a key condition for the successful building of the material and technical basis of communism and the triumph of socialism in the economic competition with capitalism.

What is the essence of this problem, what is the content of the advantages of the socialist system, and what are the ways and means for fusing these advantages with the STR?

The most important advantage is socialist property in the means of production and the absence of exploiter classes.

This fundamental characteristic of socialist relations of production leads to a number of important consequences. First of all, the results of research and development cannot be appropriated by the exploiter élite in society—individual capitalists and imperialist concerns—for they are the property of the entire people and are used for the ultimate benefit of the people.

From the socialist relations of production springs the organic unity of the interests of the state, the collective and every individual worker, and the consequent concern of masses of working people for developing and improving socialist production.

The socialist relations of production provide the basis for centralised state planning, including the planning of scientific and technical development.

The state plan for economic development covers the whole deeply echeloned process of scientific and technical progress, including the creation of material prerequisites for this development, determination of the guidelines for the development of the sciences and their coordination, the training of personnel at every level, and the establishment of a network of research institutions at every level and for every line of science and technology.

Among the advantages of socialism is also the constitutionally guaranteed right to work, the principle of personal

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[1] *24th Congress of the CPSU*, p. 69.

material interest in the results of production and remuneration in accordance with the quantity and the quality of the work done.

Finally, an exceptionally important advantage of socialism, which is perhaps the main condition for organically fusing its advantages with the achievements of the STR, is the possibility of consistent and purposeful implementation of economic, technical, structural and organisational policy by the state.

Consequently, *the advantages of socialism include both the social orientation of the results of the STR for the benefit of the working people and the possibility of accelerating its development.*

At the same time, there are specific features to each of these two aspects of the advantages of socialism.

The purposes and social orientation of scientific and technical progress under socialism are quite evident and with the domination of socialist property are realised as a perfectly natural and the only way of development.

It is more difficult to realise these advantages when seeking to accelerate the pace at which scientific and technical advances are applied in production. The socialist society is faced with the most acute need to create a mechanism for economic activity and management holding out incentives to production collectives, scientific institutions and design organisations, and all the management units of the economic organism for the most vigorous development and application of new technology and the boosting of the efficiency of production.

Socialism, the planned socialist economy provide the broadest scope for all-round scientific and technical progress. At the same time, the STR requires an improvement of many aspects of the Soviet economic activity.

The CC CPCU Repopt to the 26th Party Congress said:

"The conditions in which the national economy will be developing in the eighties make the acceleration of scientific and technological progress ever more pressing. . .

"A crucial, most vital area today is the application of scientific discoveries and inventions. Research and designing has to be integrated more closely with production—economically and organisationally. . .

"The close integration of science and production is an imperative of the contemporary epoch."

In this context, exceptional importance attaches to the following:

1. *A single state scientific and technical policy* laying down the guidelines for scientific and technical development and most purposefully and efficiently using the potentialities of scientific and technical progress for solving the key socio-economic problems in the development of society.

2. *A structural policy laying down the lines for transforming and improving the functional, sectoral and regional structure of material production* as a whole and its main subdivisions, internal proportions, the structure of major sectoral groups, and the territorial location of production. Structural policy takes into account, reflects and so ensures realisation of the guidelines of scientific and technical policy. It also includes all the problems in specialising production, because changes in the sectoral structure are nothing but specialisation of production raised to the level of industry.

3. *Production-organisation policy on macro- and micro-levels determining the system of planning, incentives and management of scientific and technical progress at every level*, i.e., the whole organisation mechanism underlying economic activity and ensuring the best conditions for speeding up scientific and technical progress.

4. *Utmost intensification of economic cooperation among the socialist countries and developing socialist economic integration.* It helps to establish sensible cooperation and specialisation of the economies of all countries in the socialist community, so making for the more rational use of all resources. Mutual consultations on scientific and technical policy, a pooling of efforts in research, cooperation and exchanges of scientific and technical achievements and mutual assistance in training personnel, all of these and many other forms of cooperation help to develop science and technology more intensively and effectively.

It is a vital necessity to elaborate and consistently to realise all these aspects of state policy.

The future of the STR begins today. The basic and most important achievements of this future have a long cycle and require long and purposeful programmes of activity, including the allocation of large-scale goal-oriented resources and intricate specific programme management. This is

why the contours of the future are largely determined by what society expects of it and how it plans it.

The USSR's powerful scientific and economic potential creates the material basis for the elaboration and realisation of the most progressive lines of this policy.

2. A SINGLE STATE POLICY ON SCIENTIFIC AND TECHNICAL PROGRESS

Within the social-production management system, the formulation and realisation of a single state scientific and technical policy and a structural policy organically connected with it have a place apart. The formulation and realisation of this policy are an instrument for tackling the task of organically fusing the achievements of the STR and the advantages of the socialist economic system.

This is expressed in the dialectics of the interaction of the elements constituting the productive forces—the means of production and man, the worker—the interaction of the productive forces and the relations of production, and the interaction of the basis and the superstructure.

Man, the subject of the development of science, technology and production, being the most active element of the productive forces, creates and uses in the process of social production all their material components, i.e., the means of production.

The advance of the productive forces, the growing capacity of the means of production, tend correspondingly to enhance man's potentialities in exerting an influence on the environment and on the material productive forces for their radical modification, i.e., the potentialities for producing more powerful and fundamentally new and more productive means of production. For its part, progress in the material productive forces helps to increase not only the material, but also the intellectual and creative potentialities of man himself.

Consequently, the progress of the material productive forces enhances the potentialities and importance of the personal factor of the productive forces and its active influence on their material components.

Together with the improvement of the relations of production, this results in a growth of the potentialities and ac-

tive role of the superstructure, the socialist state in the first place, within whose functions increasing importance attaches to the long-term and operational planning and organisation of the whole process of expanded socialist reproduction. These functions are expressed above all in the formulation of *economic policy*, which determines the social programme and the purposes and goals of society's production activity. The economic policy of the mature socialist society is realised through *scientific, technical, structural and production-organisation policy*, which determines the lines of scientific and technical development, changes in the structure of production and the economic-mechanism system that ensures the purposeful functioning of social production.

Consequently, state scientific and technical policy is an important form in which the superstructure exerts an active influence on the basis of the mature socialist society. It is actively involved in the shaping of the material and technical basis of communism and determines the adequacy of the material structure to the socio-economic tasks whose fulfilment that basis is designed to ensure.

It may be said that the single state scientific and technical policy, the bond between the economic policy of the socialist state and the science—technology—production chain is an aggregation of ideas which determine:

a) priorities in the development of the basic and applied sciences;

b) priorities in the development of the basic natural and social sciences and the establishment of complexes of problems which are the most important for society and which these sciences need to elaborate;

c) priorities in the development of technical systems and the laying down of guidelines for changes in the material structure of technology itself: instruments of labour and production facilities, objects of labour and methods for every sector of social production;

d) specific lines of technical, technological and production-organisation solutions for complexes of sectors and individual lines of production;

e) principles for organising production, use and repair and modernisation of machinery; guidelines for specialising engineering;

f) criteria of socio-economic effectiveness of scientific

and technical progress, the requirements made on machinery from the standpoint of the content and nature of labour and protection of the environment;

g) policy in depreciation, periods of renewal and modernisation of machinery.

This crystallises the complex of the basic economic problems of scientific and technical policy.

The scientific basis for formulating this policy is provided by studies of:

the whole range of current and long-term requirements of society, the aggregation of socio-economic goals, which it sets itself in the foreseeable future;

the logic and foreseeable prospects in scientific and technical development along their main lines;

the potentialities offered by scientific and technical progress with its foreseeable lines and prospects and with an eye to their economic effectiveness.

Here it is necessary to take into account the complex interaction of these aggregations: on the one hand, the active influence of scientific and technical progress on social requirements (non-production and production) and on the other, the impact of specific planning and financing of the whole science—technology—production chain on the development of the various lines in basic and applied research and development.

In the mature socialist society, state policy on science and technology is designed to select the lines that would provide the optimal conditions for fulfilling the basic socio-economic tasks of communist construction, while creating all the prerequisites for a balanced advance of science and technology.

The main propositions of state scientific and technical policy are, of course, historically rooted. They must reflect the historically shaped features in the development of the productive forces of a given country, the specifics of the division of labour, external economic ties, and the complexes of solved and outstanding socio-economic problems.

Consequently, the single state scientific and technical policy should be shaped in the light of the need to attain the ultimate goal of socialist production, which is the steady satisfaction of the people's growing requirements, and the fulfilment of the chief economic task of the Party and the

people, the building of the material and technical basis of communism through the use of STR potentialities and with an eye to the specific features of the material and technical basis of socialism which had been shaped in the USSR by the end of the 1970s. Such a policy must be adequate to these socio-economic tasks and give them concrete expression in science, technology and production.

The material basis for realising the single state scientific and technical policy is provided by goal-oriented state planning and financing of every echelon of scientific and technical progress: research (basic and applied); development and engineering; production and the development of research technology, and the development of engineering as a whole; equipment of material production, the non-production sphere and everyday life with the new facilities; and training of specialists and development of occupational training and general education.

The USSR's scientific and technical policy is formulated with the participation of the USSR Academy of Sciences, and leading scientists from its numerous institutes, the academies of sciences of the Union Republics, teams of scientists from sectoral research institutes, the main sectoral ministries, the State Committee of the USSR Council of Ministers for Science and Technology, and the State Planning Committee of the USSR Council of Ministers (USSR Gosplan). The economic institutes of the USSR Academy of Sciences have an important organisational role to play in these projects. Over the past few years, these projects have assumed the form of a complex programme for scientific and technical progress and its socio-economic effects over a period of 15-20 years.

Consequently, the state scientific and technical policy contains the last word and prospects of basic and applied science and the whole of technical experience.

Let us now consider its main lines and propositions.

The Soviet state's long-term policy *in the sphere of science* starts from the need broadly to develop basic theoretical research in every main field of the natural, technical and social sciences. The CC Report to the 25th Congress of the CPSU says: "People are right when they say that there is nothing more practical than a good theory. We are perfectly well aware that the high-tide torrent of scientific and tech-

nical progress will exhaust itself unless it is constantly nourished by fundamental research.

"It is the Party's policy to continue showing tireless concern for promotion of science."[1]

The social sciences face major tasks in elaborating and realising the technical policy.

In the mature socialist society, the single state technical policy, in effect, expresses in concrete terms society's requirements for scientific and technical progress. It selects the scientific, technical, organisational and production-organisation lines and solutions ensuring optimal conditions for satisfying the social requirements of the sophisticated and steadily developing socialist economy. The social sciences—political economy, the complex of sociological and psychological sciences, and philosophy—have the chief role to play in working out the scientific principles of this "social order", in establishing society's current and foreseeable requirements, in the whole complex of material and spiritual values, including the content, conditions and nature of labour itself, taking into account the requirements arising from society's advance to the higher phase of the communist formation.

The modelling and long-term planning of the social programme for society's development: the structure and volume of the necessary consumer goods and means of production, the projection of the functional, sectoral and regional structure of social production; the modelling of demands which the harmoniously developed man of the mature socialist and—in the foreseeable future—of the communist society will make on the content, conditions and nature of labour, and on that basis the modelling of demands on the nature and structure of the production apparatus and the technology of production, in the working out of all these scientific principles of technical policy, the leading role must undoubtedly belong to the social sciences.

The Guidelines for the USSR's Economic Development from 1976 to 1980 specifically designate the following key development lines in the social sciences:

elaboration of the theory of the building of the material and technical basis of communism, improvement of social

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[1] *Documents and Resolutions. XXVth Congress of the CPSU*, p. 57.

relations, shaping of the new man, and development of the socialist way of life;

development of research into STR problems, and enhancement of the efficiency and intensification of social production.

Each of these problems—social relations, new man, way of life—is directly connected with the shaping of the scientific principles of technical policy, above all, because all of them are developed and solved through the building of the relevant material and technical basis. The sphere of material production, the sphere of services and the creation and promotion of knowledge and spiritual values, the sphere of science and scientific research, are integrally inter-connected; their development and progress provides the basis for changing and improving social relations and then the shaping of new highly and harmoniously developed man takes place; they create all material components of the new way of life—housing and everyday facilities, forms of human relations, the level of culture and the spiritual values generally, forms of rest, recreation and entertainment, etc.—and ensure progress in the highest zones of the spiritual potential, all-round progress of the basic and applied sciences.

Each of these three spheres can fully function and develop only on the basis of the development and improvement of its material and technical basis. The task is correctly to determine the basic structural characteristics and criteria of maturity corresponding to the material and technical basis, i.e., the requirements which each of these spheres makes on scientific and technical progress and material production, designed to produce the technical facilities for them. It is up to the social sciences, economics in the first place, to elaborate the whole complex of problems, its methodological aspects, its material and dimensional characteristics, stages and deadlines for their solution (with the use of the specific programme method) and, of course, the calculation of inputs and efficiency.

The scientific elaboration of the economic mechanism—methods of planning and management of the economy, including ways of stimulating scientific and technical progress—is a problem of exceptional importance before the social sciences.

When formulating the tasks in the sphere of science as a whole, the socialist state brings out this complex of prob-

lems facing the social sciences. For their part, the social sciences have the main role to play in scientifically backing up the main lines of state scientific and technical policy.

State policy in the development of the natural and technical sciences looks to a combination of further expansion of basic theoretical research in every field of human knowledge and elaboration of problems helping to tackle the most meaningful tasks facing the economy in the foreseeable future. This general line of scientific and technical policy was clearly expressed in the section on the development of science in the Guidelines for the USSR's Economic Development from 1976 to 1980 (Tenth Five-Year Plan).

The extension of research in theoretical and applied *mathematics* goes hand in hand with the development of scientific work in improving computing facilities and their effective use in the economy.

The development of theoretical and experimental research in *physics*—nuclear, plasma, solid-state, low-temperature, radiophysics and electronics, quantum electronics, mechanics, optics and astronomy—goes hand in hand with the development of atomic power and the formulation of the scientific and technical principles of thermonuclear power, the perfection of existing and elaboration of new modes for the transformation of energy, the development and extensive use of fundamentally new technology, new structural, magnetic, semiconducting and superconducting and other materials.

The further development of basic *chemistry* goes hand in hand with an extension of research into the synthesis of chemical compounds to obtain substances and materials with new and pre-set properties, the development of new chemical processes with highly effective catalytic systems, ensuring a marked acceleration of chemical reactions, elaboration of the improved principles of processes, the preferential use of closed-cycles and gradual switch to waste-free methods.

The development of every branch of *biology* goes hand in hand with the elaboration of ways to speed the solution of the key medico-biological problems in combatting cardiovascular, oncological, endocrin, viral and occupational diseases and diseases of the nervous system.

Specially designated is the further elaboration of the theory and methods of genetics for producing new and valu-

able varieties of plants, breeds of animals and cultures of micro-organisms, and also ways of obtaining physiologically active substances for medicine, agriculture, and some industries.

Science has also been set the task of developing the scientific principles for rational use and protection of soils, subsoil, flora and fauna, air and water, and extension of the exploration of the World Ocean, the Earth's crust and the upper mantle of the Earth.

Efforts are to be continued in the exploration and mastery of outer space, extension of research in the use of space facilities in the study of the Earth's natural resources, in meteorology, oceanology, navigation, communication and so on.

The scientific and technical policy of the mature socialist society, oriented upon the building of the material and technical basis of communism, integrates R&D in the natural sciences into basic systemic complexes determining the progress of material production and the steady perfection of man, society's prime productive force.

These integrated efforts of the natural and technical sciences will have to concentrate in the foreseeable future on the following major problems:

development and improvement of the energy base of production and the non-production sphere;

development of the instruments of labour and creation of production facilities adequate to the material and technical basis of communism, ensuring high socio-economic efficiency of the means of labour;

supply of social production with modern objects of labour;

introduction of progressive techniques promoting high productivity of social labour, productivity of resources and efficiency of production, the fullest and most complex use of resources of production, creation of working conditions and nature of labour adequate to the mature social society and protection of the environment;

advance in health services, prolongation of life, and man's physical, intellectual and spiritual perfection.

As applied to each of these problems, state technical policy maps out the solution of two complexes of problems: material and technical problems which determine the key lines of technological solutions, and socio-economic prob-

lems which determine the economic and social aspects of the choice and use of technical facilities.

A progressive scientific and technical policy *in the sphere of the instruments of labour* is of key social, technical and economic importance. This most important element of the productive forces determines the capacities, technical level and efficiency of the production apparatus, and consequently, the potentialities for boosting material production and equipping the services and science and determining the content and nature of labour and working conditions, i.e., the solution of a number of basic social problems in communist construction.

The key problems in building the material and technical basis of communism are being tackled in this sphere, and this determines the need for in-depth and scientifically well grounded elaboration of technical policy on the instruments of labour and the closely related structure and organisation of engineering, a complex of industries producing, developing and renewing production facilities in every sphere of the economy.

Formulating the basic lines of technical policy, the 24th Congress of the CPSU set this task: "To create and introduce fundamentally new instruments of labour, materials and production processes superior in their technical and economic characteristics to the best Soviet and world standards."[1]

The solution of this key and highly complex problem means that in the epoch of the STR the existing production apparatus, largely based on principles of traditional technology, *should not reproduce itself but create fundamentally new technology, new types of products* which frequently differ radically from those on the basis and for the production of which they were developed. Realisation of this fundamental technical-policy principle will help to realise the achievements and potentialities of the STR. Conversely, failure to practise this principle would mean that industry itself will create the obstacles which in the 1980s and 1990s will turn out to be a drag on technical progress.

This is connected with another and highly important technical-policy principle, also formulated in the Directives of the 24th Congress of the CPSU: "To raise more rapidly

[1] *24th Congress of the CPSU*, p. 249.

the technical level of the stock of industrial equipment, and also to accelerate the replacement and modernisation of morally obsolescent machinery and units, and to provide for the adequate development of the branches of engineering concerned; to work out and gradually introduce new schedules providing for shorter periods of depreciation of production equipment, limiting the volume of ineffective overhaul, and increasing the proportion of depreciation allowances for the replacement of worn-out and morally obsolescent equipment."[1]

The traditional practice in the distribution of engineering products results in a slow-down of the rate at which old machinery is renewed. At least two-thirds of these products go to newly built works and expansion of enterprises and also for export, and only about one-third—and even less, according to some calculations—goes to replace obsolescent hardware.

There is a need for the utmost intensification in the use of the existing stock of equipment and a substantial change in the proportion between overhaul of old machinery and the development of engineering turning out new machinery, in favour of the latter.

Acceleration of scientific and technical progress requires much faster replacement of the existing production apparatus. Where at present a service-life of about 15 years—and 10 years for electronic facilities—is regarded as progressive, these periods are bound to be shortened in the future. But this question naturally arises: is it posible to produce sufficiently reliable and highly productive facilities that would recoup themselves over a shorter period without any substantial increase in the cost of the output? Or, formulating the question in a different way: can the productivity of this technology grow fast enough to prevent any marked increase in the cost of replacing such rapidly growing volumes of depreciation charges and to prevent their growth per product-unit? After all, with every successive reduction in the service-life of machinery, the volume of these charges does not merely increase in absolute terms, but also tends to grow at en ever faster pace.

There are boundaries beyond which reduction of the service-life of machinery no longer makes economic sense.

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[1] *Ibid.*

At the same time, the pace of scientific and technical progress requires a considerable reduction in the periods for the technical renewal of the instruments of labour.

The existing situation determines the need, through an appropriate technical policy, to solve the problem of enhancing the economic indicators of the renewal of machinery. This problem should be solved at the stage at which machinery is engineered. The most important demand which must be made on engineers is that the *new machinery, while being highly progressive and highly productive, must also be flexible, that is, it must easily lend itself to radical modernisation, to switching without substantial inputs into the making of fundamentally new and more progressive products, and to adapting itself to the use of fundamentally new techniques.*

The technical renewal of production facilities should also be effected through the modernisation and readjustment of existing facilities unit-by-unit. But if modernisation is truly to raise the technical level and bring it up to modern standards, it must be organised on truly industrial lines.

The Directives of the 24th Congress of the CPSU set the following task: "To effect a gradual transition from the practice of decentralised manufacture of aggregates, units and parts intended for modernisation and repair of equipment to their specialised production organised at the enterprises manufacturing the equipment in question."[1]

Consequently, the socialist society is faced above all with the task of exercising unremitting state control to make sure that there is no manufacture of instruments of labour which may subsequently turn out to be impediments to technical progress. The socialist state's technical policy also requires that there should be no production of equipment which cannot in the near future be switched to the manufacture of new and more progressive products.

This range of technical-policy problems could without exaggeration be called problems in the state protection of technical progress, as the state ensures the balanced realisation of the STR's potentialities. These problems largely determine the pace and economic efficiency of scientific and technical progress, and the pace and efficiency of social production.

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[1] *Ibid.*, p. 250.

The present state of the Soviet economy and the tasks of its development over the foreseeable future dictate the need and appropriateness of bringing to the fore the following key technical-policy lines:

First, development and use of technology, means of labour and techniques ensuring a high rate of mechanisation of manual operations, above all arduous physical labour. In the USSR, nearly one-half of the workers in industry and building and also sizable amount of workers in agriculture, transport and in the non-production sphere of the services are engaged in manual labour.

There must be accelerated and specialised development of the following: the means of mechanisation and automation of hoisting, transport and storage operations in every sector of the economy; mechanised manual tools and instruments for assembly, control and measuring operations; facilities for spading, finishing and ancillary operations performed in the running of equipment.

The problem of mechanising manual labour in every sector of the economy is also a social problem of prime importance the need for whose accelerated solution is closely tied in with the steady growth of living standards and the people's educational and cultural levels. The importance of this problem is further enhanced in the light of the demographic situation which is to take shape in the 1980s. It was said at the 25th Congress of the CPSU that as a result of post-war changes in the age and sex compositions, there is expected to be a sharp reduction in the influx of working-age people.

Second, development and use of technology ensuring saving not only of living labour but also of the labour embodied in the means of production; not only a reduction in labour-intensiveness but also a steady reduction in the capital- and material-intensiveness of every industry.

Solution of these problems requires extensive manufacture and application of technology ensuring more economical use of fuel and raw and other materials; development and introduction of power and electrotechnological units reducing power inputs per unit of useful effect; introduction of technology ensuring fuller and more complex use of all the useful components of raw materials and fuel, development of combination, a sharp reduction in production waste, and

a gradual switch to waste-free methods, wherever that is possible.

Third, elaboration and accelerated development and introduction of technology bringing about an improvement of quality and finishing of materials and products:

equipment and processes for heat-hardening, deformation ageing, modification, improvement of rolled-stock surfaces, mills for controlled rolling, various installations for physical action on crystallising metal, etc., in metallurgy;

hardening, finishing and honing equipment in engineering;

chemical manufacture of fine organic synthesis products providing higher quality of organic and inorganic materials, varnishes and paints reducing metal corrosion, improvement of foodstuff quality, etc.;

finishing equipment for the textile industry;

facilities for drying and chemical hardening of timber, etc.

Fourth, elaborating and realisation of a complex of measures (R&D, technological and economic-planning) ensuring a reduction in the weight of the social product: a reduction in the weight of fuel, structural materials and finished products; consistent reduction in the inputs of primary raw materials (products of agriculture, forestry, and the extractive industries) per final product-unit.

Indeed, technical progress is materialised in the new products of labour and in improved instruments of labour but it also leads to a steady complexification and specialisation of equipment, making it more reliable and giving it a longer life, while simultaneously, of course, increasing its cost. All these are undoubtedly positive processes. But there are also serious contradictions between them. The replacement of existing equipment with new equipment, before the former has been fully depreciated, is fraught with large losses of the value embodied in existing production assets. Similar losses are connected with the need to produce new products if it turns out that existing equipment needs to be replaced with new equipment. Finally, the renewal and extension of the range of products reduces the massiveness of production and limits the size of batches.

Society cannot afford to slow down the pace of technical progress, and equally it cannot afford the large losses arising from the premature write-off of the fixed assets. This contra-

diction can be resolved through the use of a key principle of progressive and flexible technical policy in machinery and production organisation.

When the instruments of labour cannot at all or only with great difficulty be switched to new production methods or to the manufacture of new and more progressive products, when it is hard to modernise them in the light of the STR's achievements, all of this, together with high reliability and long service-life, adds up to factors operating for a technical "counter-revolution".

The provision of flexibility entails a complex of measures:

1) Extensive unification and standardisation of parts and units of machines and other items; design of units and assemblies and of complete plant in the form of size-series which make it possible to run flow-line and large-batch production of parts and units of batch- and even piece-products;

2) The aggregate principle for developing equipment, i.e., the manufacture of machines consisting of changeable various-purpose units, which makes it possible easily to change their technical parameters (by changing the aggregates) and switching them to the manufacture of new types of products;

3) Specialised manufacture of rigging which can be rapidly readjusted (and the making of machine-tools adapted to the swift change of rigging), which makes it possible to reduce the difficult problem of mastering new products to the readjustment of flexible equipment;[1]

4) orientation of automation in engineering and other industries upon programme-controlled machine-tools and equipment, with massive output of standard and easily readjustable programmes;

5) planning of shops and sections in space, and the laying of power and other communications, and the arrangement and installation of equipment in such a way that whenever there is a change of product, the spatial arrangement of equipment can be easily altered and the necessary products and product-closed sections working on the flow-line principles can be formed.

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[1] Machine-tools and other similar machines should be increasingly converted into long-life and reliable foundations for changeable units and rigging. Because the basic units (frames, etc.) are the most material-intensive, such an approach will also help to reduce material-intensiveness.

An important means for ensuring flexibility is improvement of the organisational structure of production through a rational combination of large, medium and small enterprises.

As the structure of demand for the means of production and consumer goods becomes more complex, there is a reduction in the massiveness of output. For its part, satisfaction of requirements in light, non-massive and frequently also small-batch, piece and now and again out-of-standard products has a negative effect on productivity and the efficiency of large and highly specialised plants. The frequent readjustment of their equipment is much too costly. Small enterprises, well provided with universal equipment, undertake to turn out small-batch production, thereby leaving the large enterprises free for efficient and mass production.

This organisation is exemplified by many steel mills which release large metallurgical giants from the making of light rolled stock and supply consumers with metallurgical products in a wide range of grades, sizes and sections.

Realisation of the flexibility principle will require extensive synthesis of the functional and product-specialisation of the instruments of labour and the manufacture of aggregate equipment. Fundamental importance in this connection attaches to the functional approach in design of equipment, which makes it possible to establish units with identical functions (motors, reductors and transmissions, filling and cooling systems, ventilators, etc.). After due adjustment, such units can be mass produced by specialised enterprises and then, as the need arises, be used to make up various mechanisms, machine-tools and transfer-lines, and just as easily re-arranged in accordance with the changing requirements of production.

> The Committee of Standards, Measures and Measuring Instruments of the USSR Council of Ministers has estimated that the aggregation method helps to reduce the volume of design work 5-6-fold as compared with the conventional design of the same type of equipment. The use of ready-made standardised units and mechanisms in the fabrication of aggregated machine-tools reduces the length of the production cycle 4-5-fold and helps to turn out a new machine-tool 2.5-4 months earlier than the usual period of one year.

The solution of this problem also requires systematic work in standardising, unifying, normalising and typifying the products of labour, the instruments of labour and the technological process, the development and introduction of rational size-series[1] of equipment, instruments and mechanisms in all the branches or engineering.

The socialist economy provides all the necessary conditions for organising work on a national scale in unifying, normalising, typifying and elaborating the size-series of machines.

Engineering, like every other sector of the socialist economy, must be oriented upon the most economical satisfaction of the requirements of the user-sectors. In this context, *an important technical-policy problem is to combine the steady improvement of technology and the constant tying in of capacity and size parameters with the actual requirements of production and the conditions in which the machines are used.* The Directives for the Ninth Five-Year Plan period stated the need to turn out machines with a broad spectrum of capacities corresponding to the requirements of the economy, notably small motors and micromotors.

In designing new technology, the task may be to save inputs of labour, materials or assets, which is why a *key problem that needs to be taken into account when the main lines of technical policy are formulated is to determine rational proportions between economies of living and past embodied labour.* This, for its part, is connected with the selection of the main ways in boosting labour productivity.

The Guidelines for the USSR's Economic Development from 1976 to 1980 emphasised that one of the central tasks of technical policy now and in the foreseeable future is reduction of material-intensiveness and improvement of the output-assets ratio. These tasks are important for a number of reasons.

The growing importance of saving past labour inputs (naturally, alongside with the steady boosting of the productivity of living labour) is determined by the vast scale and

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[1] Size-series are groups of similar-type machines consisting of standardised units and parts. Each machine in this series is designed for the working definite-size parts. The whole aggregation of machines in this series is capable of machining parts of any size, which is why it makes it possible to arrange sets of machines in complex-mechanised and automated lines.

the growing share of material inputs in the cost of production.

The main technical-policy line on the *objects of labour* is marked improvement in the quality of the traditional production materials, metals in the first place, timber for industry and building, structural materials, and also materials for the light and food industries: fibre, leather and other products of plant-growing and stock-breeding.

In metallurgy, as in other industries, there should not only be an effort to develop specialised production of especially high-quality sorts of materials, like high-quality steels, but also *considerably and systematically to improve the quality of the bulk of these materials*, i.e., the introduction everywhere of hardening conversion, as a basic component part of the technological process.

Today, when the USSR produces 150 million tons of steel a year, almost 130 million tons of cement, and 100 million tons (in conventional units) of mineral fertilizers, etc., metallurgy and a number of other industries look like pre-historic dinosaurs whose skeletons can no longer hold their weight.

Orientation of economic and technical policy on efficiency and quality implies a sharp swing in all scientific and technological R & D towards ensuring at every stage of production improvement of the quality characteristics of the materials turned out both for the means of production and for consumer goods.

The manufacture of the objects of labour should be oriented upon the fullest and most effective satisfaction of social requirements both in terms of quality with an eye to the conditions in which they are used (nature of exploitation, climate, etc.) and in terms of assortment (size and gauge of rolled stock, lighter sections, approximation even at the stage of production to the form and properties of the final products, etc.).

Industries turning out objects of labour must undertake a greater share of the work in preparing and finishing the material and fulfil a number of functions in initial shaping. This accords with the general technical-policy principle formulated at the 25th Congress of the CPSU about enhancing the role of operations to completely prepare the finished product for consumption. This expresses the orientation upon the consumer.

Another key technical-policy task in the objects-of-labour sphere is the expansion of production of man-made and synthetic materials with pre-set properties. Here again there are the tasks of improving quality and assortment. At the same time, the ecological aspect is highly important.

Another important line springs from the overall task of *reducing the cost of the whole social product.* This calls for the elaboration and realisation of complex design, development, technological and economic-planning measures aimed to reduce the weight of fuel, structural materials, and finished products, and a consistent reduction in the per-unit inputs of each of these elements.

Consequently, at the present stage in the development of the mature socialist society in the USSR, the task of steadily boosting the efficiency of production, which has now become central, must be regarded as a complex task in economising on the aggregate inputs of social labour, both living and embodied. Technical policy is directed precisely to such a complex approach in assessing the effectiveness of all technical solutions. The boosting of the productivity of living labour by worsening the output-assets ratio with a low level in the use of fixed production assets does not meet the policy of intensifying production.

The leading technical-policy principle—in economic terms—which should dominate the process of development and introduction of new technology is to secure the priority growth of its productivity as compared with the growth of its cost and price.

The socialist state's technical policy proceeds from the assumption that over the long term there is a need for systematically elaborating and gradually mastering and introducing in the key production sectors the systems of automated machines and techniques adequate to the material and technical basis of communism: automatic equipment and its most progressive type—numerical programme-controlled equipment—robots of the latest generations, mini-computers for optimising and controlling technological processes, waste-free production methods, etc., and the creation of a scientific and technical stock in these areas. Alongside systematic progress in automating production, much importance attaches to the development through the use of cybernetic devices of its highest form—modelling and op-

timisation of processes and control of production at optimal regimes.

The realisation of technical policy largely starts and runs a considerable part of the way in *engineering*. In the USSR, as in all industrially developed countries, it has become a gigantic complex consisting of dozens of industries with the most complex external, intersectoral (outside engineering), intrasectoral (within engineering) ties.

> According to the Central Statistical Board of the USSR, in 1976 engineering and metal-working turned out 25.1 per cent of the USSR's industrial output, and employed 40.6 per cent of the industrial personnel in the country; 22.5 per cent of all the fixed production assets in industry were operated at enterprises within this complex.

Despite the tremendous range of the most diverse products turned out by engineering plants, they all have in common either similar or analogous products of labour, objects of labour and also largely instruments of labour and techniques.

The development of engineering intensifies specialisation and cooperation processes. Items turned out by dozens and hundreds of different plants are assembled into units and machines on the conveyer lines of large engineering works, and this inevitably and insistently requires unification of many construction and technological solutions.

In these conditions, exceptional importance attaches to *the pursuit of a single technical policy in engineering itself, a policy that is unified within the framework of each ministry and for the whole of engineering.*

The coherent technical policy in engineering is the most important (and in many respects, the leading) element of the single state technical policy as a whole.

The technical-policy lines described above fully apply to engineering, as they do to other industries, but there are a number of technical-policy problems which apply specifically to the whole of engineering.

The development of a system of machines is one such general-engineering problem. The Guidelines for the Tenth Five-Year Plan say: "To pass on consistently from developing and introducing individual machines and production processes to the designing, manufacture and large-scale

use of high-efficiency systems of machines."[1] This line was also continued in the Guidelines for the Economic and Social Development of the USSR for 1981-1985 and the Period up to 1990.

There are several aspects to the systemic approach in the development of machines. First, in the design of each type of machine there must be provision not only of the high nominal productivity of the unit, but also of its efficient exploitation, and easy-repair capability. Second, the systemic approach means the provision not only of a high level of mechanisation of individual processes, but also the all-round equipment of production as a whole with machines; consequently, as a rule, complex machine systems need to be designed and made for each industry. Third, when new machinery is designed and manufactured there is a need to take into account the possibility of modernising similar machine already in use, and future machine.

When analysing the economic problems of technical policy, one has to consider yet another important aspect of the systemic approach, namely, the consideration of every type of hardware (when it is designed and made) as a component unit of the whole system of machines existing in modern material production.

As it was noted above, with the tremendous diversity of industries and types of machines, ever more numerous sectors and types of engineering products are brought together in functional, design, technological and organisational terms by the fact that many of their elements are of the same or similar type. This determines the functional and construction similarity of units of the most diverse types of machinery.

Motors, transmissions, reductors and other drive mechanisms, fuel, air and water supply systems, cooling systems and transfer, control and management systems, all of these and many other functional units are available in the most diverse types of technical arrangement. The systemic approach to engineering implies an analysis of machinery in the functional plane to bring out these functional subsystems and in some cases, an approach to the design of new systems from the functional standpoint, an approach

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[1] *Documents and Resolutions. XXVth Congress of the CPSU*, p. 185.

which helps to find totally new solutions (as, for instance, in the switch to printed circuits in electronics).

This opens up a broad field for fundamentally new, original and progressive technical solutions and the development of intersectoral lines of production of the highest functional class on that basis.

Among the key problems and tasks of state technical policy is the effort *to ensure high quality of machinery and the products it turns out.* The Tenth Five-Year Plan has been designated as a period of quality and efficiency. Solution of these problems largely depends on engineering, which has to ensure the necessary technical rigging of processes improving the qualitative characteristics of the machinery and of the products it turns out.

Solution of the problem of quality requires a complex approach. I think that all the components which go to shape the quality of machinery need to be taken into account when technical policy is elaborated and implemented, despite the fact that these components are realised in definite technical solutions. Several complexes may be brought out within the makeup of these components.

The first covers such traditional technical and economic characteristics as productivity of machinery and its efficiency, reduction of inputs of resources (fuel, raw and other materials) per product unit (per unit of effect), reduction in weight and size, enhancement of reliability and lengthening of repair-free periods, and increase in the convenience of exploitation.

The second complex is the extent to which machinery and consumer goods correspond to the social requirements that they are designed to meet. This includes the abovementioned need to tie in the capacity and size parameters of equipment with the conditions in which they are actually used, flexibility of machinery, realisation of the systemic approach to the equipment of each line of production, production section or production as a whole.

The third complex includes the time factor, i.e., the length of the production cycle in the manufacture of machinery and the duration of the periods in the course of which it begins regularly to turn out products in accordance with its designed capacity. This complex is directly connected with the output-assets ratio and such a key factor as the time it takes to handle the new hardware. In the 1960s

and 1970s, the output-assets ratio in the USSR showed an unfavourable dynamic, one of the reasons being the long time it took to bring new production facilities to the designed capacity.

There is every reason to assert that a long "mastery" period in the installation of batch-produced machinery is not at all a necessary stage in the process of technical re-equipment. The manufacturers must guarantee short periods of its installation. For this, it is important to create at the design bodies, experimental plants and enterprises—those which turn out the new technology—production and technical conditions which are adequate for bringing this technology to the designed capacity even before it is sold to the users.

The Guidelines for the USSR's Development in the Tenth Five-Year Plan period say: "To make provisions for arranging the delivery of sets of complex equipment throughout the production process with rendering of expert assistance in assembly work and the carrying out of industrial tests, and also handing it over to the customer on the condition that the designed capacity (productivity) is attained."[1]

The 25th Congress emphasised the great importance of orienting production upon the ultimate economic results—meeting consumer to the utmost, "... whether this concerns primary or other materials, machines, equipment or consumer goods".[2] I think that the end result for engineering is to ensure highly efficient and economic functioning of the hardware for the user. When selling new equipment, the manufacturer have a duty to ensure its assembly, adjustment and delivery to the consumer on "turn-key" terms; to promote its trouble-free operation by fully providing spare parts and units, and wherever necessary, programmes, special tools and rigging, and also guaranteed repair and other services.

These problems are already being tackled. The Kirov Works in Leningrad, for instance, has set up a number of stations to help consumers run and repair its machinery up to a high standard. The Ministry of the Machine-Tool Industry has already got down to setting up group centres for drawing up programmes for numerical programme-

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[1] *Documents and Resolutions. XXVth Congress of the CPSU*, p. 200.
[2] *Ibid.*, p. 71.

controlled machine-tools. Users of numerical programme-controlled machine-tools made in Ivanovo send the most intricate parts for trial machining to the plant's department of assembly and adjustment. Representatives of the customer and engineers of the manufacturer jointly work out the techniques, draw up the programme, select the tools and carry out the trial machining. This is a test for the maker and a school for the customer. V. Kobaidze, director of the plant, says: "We have been selling machine-tools, but the need is to sell techniques."

There is yet another important technical-organisation problem in the specialisation of engineering. Apart from the traditional forms—product, technological and unit specialisation—*functional specialisation* is also highly important for this sector. Motors, transmission mechanisms, air and water supply and cooling systems, systems of transportation, control and management, etc., all of these units are to be found in the most diverse types of technical devices. This opens up broad potentialities for setting up specialised intersectoral lines of production and new highly progressive technical solutions. What then needs to be done for this purpose?

The first thing is to bring out the functional units and parts which are common to many technical systems (and this is a task not only for the engineering ministries but also for the researchers). This should be followed by a gradual development of specialised lines of production in accordance with the manufacture of these units and parts, with the lines of production being intersectoral to the greatest possible extent. Accordingly, machine research should become a field not only for engineers but also for economists, who will work together to comprehend the trends in the development of machines, the structure of modern and foreseeable technical devices from the standpoint of the best organisation of the engineering complex as a whole.

The manufacture of bearings is a classical example of functional specialisation. These items are used by absolutely every engineering industry, without any having the intention of setting up its "own" bearing production. Socialist engineering should develop according to this model. Only then will the consumer be able to make broad use of ready-made and technically progressive blanks, fasteners, metal

surfacing, etc., and also of functional units, like motors, which are now being made by enterprises of many ministries. Of course, such a readjustment is a difficult undertaking, but it is a necessary one. After all, it means a substantially more rational use of the production resources already being expended, acceleration of technical progress and a more progressive organisation of production.

Finally, the last (but not the least important) complex characterising the quality of machinery is its correspondence to the social criteria, the provision of working conditions and the nature of labour adequate to the requirements of the developed socialist, and in the future, communist society. This approach to the quality of hardware requires the solution by technical policy of some economic and organisational problems.

Consistent improvement of quality with a steady reduction in costs and the price of per-unit effect (or productivity) of each successive type of the given line of hardware is a uniformity of technical progress and one of the key economic criteria of machine efficiency.

An important range of technical-policy problems relates to *the lines of change in the material structure of the machinery itself*; *instruments of labour and the production apparatus of social production as a whole.*

What are the perspectives in this area and the approaches to determining the chieftechnico-economic aspects of technical policy? It is up to large collectives of scientists and practical workers to examine this highly complex range of problems, which is why I do not claim to give an exhaustive exposition of them here. This examination should, apparently, be started with the comprehensive economic classification of machinery and equipment (whether existing or foreseeable), grouping these according to economic and socio-economic indicators. Such a classification should help to determine the main lines in the changing structure of the production apparatus, and the technical facilities functioning in the economy. Here it is necessary to take into account the fact that in present-day conditions—and even more so in the foreseeable future—machine systems will be introduced not only into sectors of material production but also into every sphere of human activity, for these technical systems will have not only material goods as the object and result of their operation.

The structural classification of all types of machinery must be dynamic in the sense that it should reflect the foreseeable trends in the development of the machinery itself and the changes in society's demand and requirements. The classification can and must also serve as the basis for a structural dynamic model of engineering output and the general lines in the development of engineering itself.

Technical policy is, naturally, formulated in advance, which is why the structural classification should also include the classes and types of hardware which already exist and which will remain in the foreseeable future, together with those which are just taking shape and whose development is dictated by the socio-economic requirements of developing society.

What then is the structure of existing and foreseeable machinery and what should its economic classification be? I think that this classification should reflect, at least, five aspects, each of which has a definite economic and socio-economic meaning and brings together all types of technology in accordance with the indicators characteristic for the given aspect (see Table on p. 266). These five aspects together give an economic characterisation of the production apparatus and of all the machinery functioning in the economy generally.

Such, I think, is the general characteristic of the structure of the instruments of labour and the basic technical systems at the present stage and in the foreseeable future, in the light of the trends of their development and changes under the impact of scientific, technical and socio-economic progress.

Technical policy, especially its economic aspects, must envisage the lines, scale and time parameters of structural changes in each of these aspects. Accordingly, it is important to map out in the development of engineering over the long term the ways and priorities for the production of machinery and the gradual satisfaction of the needs of production.

Without claiming to characterise the fundamentals of such a plan, let me try to sketch out some of the crucial lines.

The first of these aspects in the classification of technical facilities (see the Table) gives a general structural characterisation for the machine system of foreseeable produc-

Five Aspects of Classification of Technical Facilities

A. Functional role in overall social production	B. Objects of labour used and nature of final product	C. Methods of acting on objects of labour	D. Nature and extent of automation	E. Social effect
I. In material production 1) power units 2) working machines 3) modelling and controlling devices 4) servomechanisms with feedback functions II. Research facilities III. Facilities in the production of services and spiritual values IV. Domestic facilities	1. Facilities extracting and processing material objects and producing material products of labour and power: motors and technological equipment 2. Mechnisms and devices transporting and moving objects and products of labour 3. Control and measuring instruments and devices appended to material objects and products of labour, and producing information 4. Devices for protecting the environment 5. Computers, including analog devices, processing and producing data 6. Devices processing material objects of labour and data and using services and social values	1. Movement in space 2. Measurements, manipulation of the results of measurements (data) and recording of parameters 3. Mechanical action 4. Power, electrical and electronic action 5. Chemical action 6. Biological action	1. Non-automatic 2. Automatic devices transmitting information on process parameters 3. Automatically controlled by programme: a) without feedback b) with feed-back 4. Automatically controlled devices with optimisation of parameters and feed-back 5. With automated control of adaptive action: a) without optimisation b) with optimisation	I. According to workers' functions: 1) use of muscular power mainly for movement; 2) control of mechanism operation; 3) adjustment and maintenance of technical system, maintenance in operating state; 4) design, technological engineering and programming; II. According to the nature of labour process: 1) physically arduous 2) not physically arduous but monotonous 3) not physically arduous and diverse 4) creative work

tion and in many cases of existing automated production. This structure has four units. The first two are power units and working machines. As I showed in Chapter Two, electric power produced at specialised enterprises in a special industry, power-transmission devices and electric motors, as a rule in-built, have substituted for these two units. The third and the fourth units of our structural scheme—modelling and controlling devices and servomechanisms with feed-back functions—could be regarded as transmission devices of the automation epoch. The development, to say nothing of the functioning, of these two units is now at the initial stage. The numerous automatic control systems, despite the fact that their name contains the word "control", do not as a rule control but merely carry out the electronic processing of data.

A great deal still has to be done jointly by scientists, engineers and economists to have these units actually perform control functions. This is highly painstaking work and very specific for each sector of production. There is a need above all for data in order to produce a full description of each production process and all the parameters which determine it, a description of all the possible types of interference, their effect on the process, the methods of eliminating them, and adjusting the process to its normal regime. Only on the basis of all such data it is possible to formalise the process of production and its results and to work out a programme and algorithm of all the controlling and correcting operations. But as it so often happens, in the process of preparing production for switching it to automatic control, the need may well arise to rethink the process itself and change some of its parameters.

All of this requires a developed data system and its thorough processing, analysis and comprehension, as a basis for the mathematical formalisation and selection (and possibly special design) of computers which best accord with the specifics of the sector of production.

The facilities required for research are designated as a separate item in the global functional grouping of modern technical facilities (first aspect of the classification). This class of technical facilities has been growing very rapidly in terms of diversity, capacity and complexity. Modern science increasingly depends on the quantity and quality of these facilities and this, naturally, determines the need

to develop the relevant branches of engineering. These need to have at their disposal not only a powerful engineering design service, but also an efficient service for the spread and introduction of facilities for research. The latter is connected with the fact that in modern conditions research and experimental technology ever more frequently become, as research and experiments are successfully completed, prototypes of technological equipment for batch and frequently also for mass installation of the technology in material production.

The second aspect of the classification characterises the basic classes of technical facilities according to their character and also the end results of their functioning.

The first group of technical facilities of this aspect consists of motors and technological equipment shaping the production facilities of the present and future material production. In the development of this major group—in terms of scale, inputs of labour and resources—use can and must be made of all the achievements of the basic and applied sciences, with an eye to the rapidly changing demands of the industries in which these facilities are used.

Here progress runs through the realisation of the potentialities for increasing the unit capacity of technological equipment and also through miniaturisation and microminiaturisation, with the use of ever more powerful means of acting on the objects of labour, the systemic approach and the principle of technology flexibility. In this class of machines, special attention should be given to the means of mechanising manual labour in assembly and mechanical operations with a large share of manual labour.

There is a considerable lag in the development of the haulage equipment. Haulage operations in various industries engage between one-third and one-half of manual workers. Hence, the task of developing a powerful engineering industry turning out various transfer machinery—continuous-action, surface and elevated transport—with the whole complex of ancillary facilities adapted to the specifics of various industries, agriculture, building, etc.

The development of this group of industries also entails the manufacture of diverse manipulators effecting in-line transfers. The mechanisation of these operations is especially important because they are now being performed manually by the operators of machine-tools and other aggregates,

which leads to the idling of basic technological equipment and inefficient use of production capacities.

There are great and urgent tasks in the next class of technical devices—measuring and control instruments and devices—on whose technical level and scale of use in production increasingly depend the quality of the machinery and the final product, the quality of production processes and standards in production. This class of machinery has an essential role to play in equipping research.

The development of the above mentioned instruments helps to solve problems of the mechanisation of manual labour. Data on industrial trades in the USSR in 1972 showed that there were 985,000 controllers, quality-control inspectors and sorters, most of whom worked by hand.

Consequently, all these three classes of machinery also need to tackle, among other problems, those in mechanising manual labour. One of the tasks of the present and the immediate future is to turn out such facilities much faster, for this will help to create the conditions for tackling the key problem of mechanising manual labour, and also to overcome the difficulties arising from the obvious demographic trend leading to a reduction, from the early 1980s on, in the growth of the population of working age.

The need for accelerated development and technical improvement of the fifth class of machinery—cybernetic devices—is obvious, for here the succession of machine generations is especially rapid. Fourth-generation machines are now being developed. The basic characteristics of the fifth generation are already fairly pronounced, and will involve the use of the latest STR achievements that have been translated into technical terms.

Machinery employed in the protection of the environment and technical devices producing services and special values (the fourth and sixth classes of this aspect) largely constitute new classes of technical devices.

There is no need to demonstrate the importance of machinery designed to tackle ecological problems, but it is important to emphasise that the most effective and radical solution of the problems in this field would be to reduce the need for such machinery to the utmost by developing waste-free technological processes, especially those in which all the components of the primary raw and other materials are used to the full.

The development and manufacturing of machinery which is largely new altogether and which produces various services are a necessary condition for the further development of public health care, education and culture, and a key prerequisite for the all-round development of man. Medical engineering, the education "industry" (teaching aids, etc.), and the culture "industry" need to be built up as powerful and rapidly growing industries.

The development of this class of technical devices is an important and complex problem whose solution must involve, along with natural scientists and technicians, the customers and consumers, namely, physicians, teachers and workers in various fields of culture.

The structural changes in the instruments of labour according to the methods of acting on the objects of labour reflect the progress of technology in material production. Their ranking largely reflects the succession in time of the foreseeable shifts in this technology, together with the tasks facing the applied and basic sciences. Just now, the means of mechanical action prevail in industries with discrete products (engineering, wood-working, etc.) and energy and chemical methods of action, in metallurgy, chemistry and petrochemistry, and also some food industries. Meanwhile, the use of electronic-action and especially biological-action methods is just beginning.

In the near future, there is bound to be a growing shift towards the two latter methods in all the groups of industries, and this will be markedly promoted by research in the applied and basic sciences.

The five groups in column 4 of the Table above (see p.266) show the nature and extent of automation of the instruments of labour and reflect the advances at the stage of scientific and technical progress in this field. It is highly important to make every unit here flexible for the use of automatic programme-controlled equipment, introduction of aggregate equipment, etc.

The elements of the fifth aspect of the structural classification are also ranked in accordance with the growth of the social effect of scientific and technical progress. As I said above, the social orientation of design and engineering of the instruments of labour and techniques tends to become ever more important and even to acquire priority.

The satisfaction which man derives from work, and the

opportunities the process and its results provide for his self-expression, together with man's consistent self-improvement in the process of labour, all of these tend to convert labour into the most important value in life, into prime necessity. Consequently, with the growing productivity of labour, the socialist society will be prepared to pay for this value by means of the corresponding investments converting the instruments of labour not only into a means of producing material goods and services but also into a means for creating the vital value into which the process of labour itself tends increasingly to develop.

Technical policy on the basic elements of production is, in principle, common to all the sectors of material production, but some sectors have their essential specifics which require the identification of special lines along which the key problems in this sector are to be solved.

This fully applies to the key sector of agriculture. For all its diversity, the machinery being produced by agricultural engineering does not constitute all the means of production, or even the means of labour in agriculture. Equally, it is hardly possible to regard seeds like the hen in poultry farming, which reproduce themselves on an enlarged scale, as materials, as objects of labour in the traditional view of this category.

Land, livestock, seeds and mineral fertilizers are also means of production, and should be classified as means of labour rather than objects of labour. In this sense, the technical working of the soil, like its improvement, drainage and fertilisation with chemicals, selection and genetics in plant-growing and livestock breeding, all of these are improvements in the means of production with the aid of other means of production. Consequently, in the context of agriculture, it is the function of technical and biological systems (the latter being specific to this sphere) not only to economise on living labour but also to improve the means of production and to raise their productivity.

Scientific and technical policy in agriculture in the Soviet Union is designed to produce an optimal combination of raising efficiency and ever higher productivity of labour. Extensive basic and applied research in genetics and selection, long-term improvement of seeds and livestock, together with the use of highly progressive chemicals and land improvement, and further specialisation and concen-

tration of agricultural production, such is the highly progressive line of technical policy in this key sector of social production.

I have roughed out the contours of the structural model of the instruments of labour, the basic lines of its change and improvement in the foreseeable future as dictated by the logic in the development of the instruments of labour and the acceleration of scientific and technical progress, together with the growing requirements of the developed socialist society and the task of building the material and technical basis of communism. Consistent realisation of these trends is a key component part of state technical policy.

The state scientific and technical policy of the mature socialist society, which has been built in the USSR, is being steadily perfected, reflecting society's growing scientific, technical and economic potential, the STR's steadily progressing potentialities and the ever growing requirements of society and the people constituting it.

This policy is formulated with an eye to the future, with the perspective of the advance of mature socialism and its development into a communist society.

That is what makes the single state scientific and technical policy in the conditions of mature socialism so complicated and responsible, but also nesessary and of tremendous positive and constructive importance.

3. STRUCTURAL POLICY. INTERCONNECTIONS BETWEEN SCIENTIFIC AND TECHNICAL PROGRESS AND THE SECTORAL STRUCTURE OF MATERIAL PRODUCTION

Scientific and technical progress and the changing structure of material production are closely interconnected processes.

Scientific and technical progress exerts a most radical influence on every element of production and, accordingly, on its functional, organisational and sectoral structure. For their part, structure and its changes are not only highly important factors which determine the efficiency of production, but also the most important conditions which exert an influ-

ence on the rate of development and the effectiveness of scientific and technical progress.

Structure is one of the most important substantive characteristics of any system. It reflects the system's internal make-up, the correlation and inter-relation of its constituent sub-systems and elements, the interdependence and subordination of its constituent parts, their functional and linear ties, proportions and the conditions in which these are combined. Only a definite structure transforms an aggregation of elements and sub-systems into a purposeful system and enables it to function for a present purpose.

The analysis and planning of structure, the systemic structural approach are the key instruments of management and, above all, of planning.

The programme goal-oriented approach to economic planning ultimately starts from the structure of social requirements (and definite elements of these requirements) and is aimed to shape a structure of social production that is adequate to these requirements.

The structure of such a complex system as social production naturally has different aspects each of which characterises definite sides of the system and its functioning, and also definite sides of the social division of labour and the socialisation of production.

I think that it is most important to analyse the following aspects of the social-production structure.

The first aspect, whose comparison with the structure of social requirements helps to determine the adequacy of production to society's existing requirements (or those taking shape in the foreseeable future), is *the functional structure of the final product* of the social production, the material goods and services which are the end results of the operation of the various sub-systems, constituting the production and the non-production sphere.

Today, it is especially important to bring out the functional structure of the final product, together with its sectoral structure (which will be considered below) because in view of the rapid advance of industrialisation, division of labour and complexification of intersectoral ties, the products of an ever wider range of industries tend to be included in the make-up of the means of production. An ever broader range of products which had once been the final articles of consumption become objects of labour in the process of

further industrial working-up.[1] On the other hand, a wide range of heavy industries traditionally turning out means of production now turn out an ever broader range of diverse consumer goods.

The second aspect, which is closely interlaced with the first, but which is not identical with it, is *the sectoral aspect* of structure. Here, aggregations of producing subjects are the primary structural element, so making it possible to analyse and plan the labour-intensiveness, material-intensiveness and capital-intensiveness of production itself, which means the comparative efficiency of various combinations of sectors and sub-sectors. A comparison of this aspect with the structure of the final product makes it possible to compare the inputs of social labour for obtaining it and to evaluate the efficiency of any possible alternative structural approaches.

The development and improvement of the structure, and the extension of the potentialities of production and its capability for adapting to the growing and changing volume and structure of social requirements depend on *the production and technical potential*, on the capacity, flexibility and structure of *production resources* at the disposal of the given unit of social production. This leads to the third aspect, *the functional structure of production itself*, i.e., the elements of social production and their development in accordance with their production functions: means of labour, objects of labour, techniques, etc., and for the non-production sectors, in the operation of the enterprises and establishments concerned.

The fourth aspect is connected with *the organisational structure of production.* Once the production resources are given, their use and the efficiency of production, and also the rate of growth and development of production itself are very largely determined by the level of its organisation, which in the developed socialist society is designed to ensure a rational division and cooperation of labour: specialisation, cooperation and concentration, i.e., advance in the socialisation of production.

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[1] The authors of a book entitled *Levels and Trends in the Development of the Leading Capitalist Countries* (Nauka Publishers, 1977, p. 172, in Russian) are quite right in saying that "the sectoral structure of the economy has long ceased to reflect the functional division of products into means of production and articles of consumption".

The organisational aspect of the structure of social production can be seen from many angles: according to *function and place in the organisational process* ensuring the operation of the given system of enterprises (research institute, technological design and other institutes; organs of management of the sector: association, chief administration, ministries); and according to *the combination of the hierarchical organisational structures of management* of the given system (organs of functional, linear, and programme- and goal-oriented management).

The structure of sectors and enterprises of material production according to *the character of specialisation and cooperation and the extent of their concentration* is an exceptionally important side of the organisational aspect. The combination of large-scale, medium-scale and small enterprises, the type of division of labour and functions between them, and the nature of specialisation exert a very great influence on the development and efficiency of production.

I do not consider here the highly important regional, reproduction and social aspects of structure.

In the process of analysis, forecasting and planning, the aspect of the structure of social production characterised above must be evaluated only on the basis of a comparison both with the structure of social requirements (i.e., society's requirements at every given stage of its development) and with the input of social labour. The efficiency of every given structure is determined by how economically it helps to solve the problems facing society at the various levels.

This produces the possibility for a highly fruitful comparative analysis, modelling and forecasting, and ultimately, for planning the interaction and mutual correspondence of:

the structure of social *requirements* for whose satisfaction the given line of production or group of production lines are designed;

the structure of *the final product* of this group of production lines (the extent to which they satisfy social requirements);

the structure of *the functional elements of production* in the same group of production lines (the extent to which they make it possible to turn out the final product whose make-up and quantity are adequate to the requirements in it).

The analysis and modelling of the mutual correspondence of structures should fully take into account *the qualitative aspects*, i.e., the improvement of quality as reflected in social requirements, and the realisation of the growing demand on the quality of the final product of the producer industries and in the structure of the production resources used by these industries.

In order to make production highly economically efficient, there is a need, alongside the steady and purposeful improvement of the quality of the products, means of production and objects of labour, to avoid obtaining an economically unsound quality, when the qualitative characteristics of the end product do not correspond to rational requirements, and result in an unjustified increase in the inputs of production resources, while the means of production (equipment, materials) used have an excessive capacity, precision and—quite naturally—cost. State policy ensures the selection and appropriate stimulation of the development of scientific and technical lines and lines of production which help most fully and effectively to solve the main socio-economic problems facing society.

Scientific and technical progress exerts an exceptional influence on *the structure of the staff employed in social production.*

According to the Central Statistical Board of the USSR, over a period of 37 years the total number of persons employed in science multiplied 11-fold. The number of specialists multiplied 10-fold. Over a period of 36 years, the number of certified specialists in agriculture increased 24.1-fold, and their share went up from 0.18 per cent to 5.18 per cent.

Scientific and technical progress exerts a considerable influence on the sectoral structure of production. This is due to the fact that it tends to generate numerous new types of means of production and articles of consumption, and predetermines the formation of new industries with the growth and specialisation of the new product.

At the same time, changes in the structure of material production exert a many-sided influence on the spheres, development and effectiveness of scientific and technical progress because in the process of its development and functioning every structural element of social production makes numerous and diverse demands on technology and science.

Structural proportions, like priority rates of development

in scientific device-making, determine the course and success of research itself. For all its diversity and powerful potentialities, modern science has never been more dependent on technical facilities than it is today.

The development of electric engineering, engineering and the chemical industry provide the conditions for the technical re-equipment of the whole economy, of all the industries in which the new technology are materialised. On the development of engineering crucially depend the rates at which the production apparatus is renewed. Consequently, the structure of material production and of the key sectoral complexes is largely a condition for realising the main lines of technical policy and also a highly important factor in the efficiency of production.

It has been previously noted that scientific and technical progress exerts a great influence on all the components of the efficiency of social production. For its part, it depends substantially on the efficiency of production, because it *alone helps simultaneously to make large appropriations for boosting the well-being of the working people*—the subjects of scientific and technical progress—on the development of the heavy industry, *the extensive development of science and technology, and the country's defence.*

The sectoral structure of production has a marked effect on its efficiency in reducing material-intensiveness. The input of materials per final-product unit, or—something that reflects the same process—final product output per unit of material input, no doubt largely depends on economies in raw and other materials on the shopfloor through the improvement of machinery, techniques and the organisation of production. But for all the undoubted importance of these reserves, perfection of the structure of the basic sectoral complexes and of the whole of material production holds out much greater potentialities for increasing final-product output per unit of expended raw and other materials.

Thus, a growth in the output of pulp, paper and cardboard, with the simultaneous extensive use of the waste of deciduous species, sharply increase output per timber unit.

In the manufacture of machinery and other metal items, the switch from the use of high quality rolled-stock and castings to the use of sheet (especially thin sheet), and also rolled stock and planks of lighter-shaped sections which have been subjected to initial shaping in rolling and fin-

ishing shops in metallurgy results in a reduction of metal-intensiveness which cannot be compared with the possibilities of saving metal in mechanical working. There are very many similar examples.

The influence of structural factors on the level and dynamic of the labour-intensiveness and labour productivity is just as great.

Structural changes also have a great influence on the asset-output ratio at every level. Let us bear in mind that various industries differ markedly from each other in the level of the ratio. The power industry, the extractive industry, metallurgy and basic chemistry have a high ratio; the light and food industry, a low ratio; engineering, a medium one, and so on. Changes in the sectoral structure naturally have an effect on the average level of asset-output ratio for industry as a whole.

Such are some of the aspects characterising the influence of changes in the structure of material production on the various components of the efficiency of social production.

The socialist state, planning the use and distribution of labour and material resources, actively shapes and improves the sectoral and functional structure of material production. That is why it is so important that state structural policy should be scientifically formulated and consistently implemented.

Thus, the economic problems of structural policy and, accordingly, the structure of capital investments and the distribution of labour resources are organically included among the economic problems of scientific and technical progress.

The shaping of the technical level of production largely depends precisely on the structural factor. This is due to the obvious fact that the technical level of production is determined not only by the availability of individual units of modern equipment but also by the scale on which they are used and their share in the output of products. But the development and expansion of industries turning out new technology, and of the industries in which this technology is extensively used are nothing but improvements in the sectoral structure of production.

Finally, a rational sectoral structure, by improving the use of the basic production resources, is one of the most important conditions for perfecting the proportions of ex-

panded socialist reproduction. It helps to attain a high rate of growth in the physical volume of production, with relatively minimum inputs of the means of production. On this basis, there is a reduction in capital investments, which means also a reduction in the rate of production accumulation, i.e., in the share of that part of the national income which goes into accumulation. This releases resources for the maintenance of high growth rates in Department II, which turns out the articles of consumption, and the development of the non-production sphere.

The sectoral structure of production in the USSR always has been systematically improved. There has been a priority growth of the leading industries which determine the technical level of the economy: the power engineering, engineering, chemistry and petrochemistry. The intra-sectoral proportions have also been steadily improved.

> From 1950 to 1977, industrial production in the USSR multiplied 11.0-fold, generation of electric power 12.6-fold, chemical and petrochemical output 26.0-fold, and engineering and metal-working output 27.4-fold. While fuel output went up 6.3-fold, the extraction of oil went up 14.4-fold and of gas 60-fold. In the same period, the output of steel increased 5.4-fold, and of rolled stock 5.7-fold, while the output of rolled sheet increased 8.7-fold (1950 to 1976).
>
> During the Eighth and Ninth Five-Year periods, important and positive changes took place in the rolled-steel structure. From 1966 to 1976, total rolled-steel output went up by 60 per cent, its output from low-alloy steels with thermal hardening increased by 200 per cent, and from thin-sheet cold-rolled steel, 100 per cent. In that period, the output of bent sections went up 6-fold, and of high-precision shaped sections—19-fold.

For all these highly positive advances, the historically shaped structure of material production in the USSR still falls far short of satisfying the rapidly growing requirements of society, and has a number of essential shortcomings which have a negative effect on scientific and technical progress and tend to reduce the efficiency of social production. On the scale of the whole of industry, the share of such leading industries as power, chemicals, pulp and paper is still inadequate.

The manufacture of the instruments of labour lags markedly behind the requirements of production. The making of technological equipment for a number of leading industries has long been lagging behind their growth.

For the four most important heavy industries—electric power, chemistry, ferrous metallurgy and engineering (in 1960s and 1970s)—the growth rates of output of equipment for each of these industries were well short of the latters' growth, the only exception being the manufacture of automatic and semi-automatic lines for engineering. In the 1950s, there was faster growth in the output of turbines and chemical equipment. For electric motors, metallurgy and engineering there was also a lag in the manufacture of the instruments of labour.

Consequently, the key structural problem on whose solution largely depends the acceleration of scientific and technical progress and the efficiency of social production is the need to ensure now, and in the more distant future, priority growth for engineering, chemical industry, electric power and pulp-and-paper industry.

There are also essential shortcomings in the internal structure of large sectoral complexes. Thus, the share of gas in fuel extraction is inadequate; there is a lag in the technical equipment of the fuel industry, and this increases the per-unit inputs of fuel; the assortment and quality of rolled metal are inadequate; the structure of oil refining is of little efficiency; the structure of the forestry and woodworking industries is imperfect, with the prevalence of sawing and little development of the chemical line: the pulp-and-paper industry.

The structure of engineering calls for special examination. In present-day conditions, engineering is the most important sector on the level of whose development and structure largely depends the solution of the key problems of economic development: the technical re-equipment of all the sectors of the economy, advance in science, the strengthening of the country's defence capability, and the solution of a number of key social problems in communist construction.

Because of the vast scale of engineering (40 per cent of all workers and 21 per cent of all the fixed production assets in industry) it is of primary importance to have this sector develop at a fast pace, with a rational structure and high efficiency.

Accordingly, priority growth in the manufacture of the instruments of labour and of engineering as a whole should be one of the main proportions of expanded socialist reproduction.

An analysis of basic indicators in the operation of this sector suggests the conclusion that the efficiency of the engineering should be increased and that the inputs of the basic resources do not accord with the volume of its output. What are the basic reasons for this state of thing?

Most of these are in one way or another connected with the *inadequate specialisation of production.* This is expressed above all (for objective reasons) in the small number of enterprises with unit and technological specialisation, and a relatively large sphere of universal plants with a large set of preparatory and ancillary shops, a sizable part of which do not have optimum loading, a fact which tends to limit the use of modern highly productive equipment.

During the pre-war five-year periods, during the war and in the period of postwar rehabilitation, the USSR built up and developed its heavy industry, and engineering, its core, in that historical situation, in the absence of ramified engineering industries and sub-industries, in the absence of broadly cooperated production, and oriented itself mainly on the building of complex plants with a full set of preparatory shops and ancillary services. The first two tractor works—at Stalingrad and Kharkov, the first two automobile works—the Likhachov plant (ZIL) and the Gorky motor-works (GAZ), were all designed as complex plants. The existence of these plants, which had a tremendous role to play in the country's industrialisation, proved to be an inertial force complicating the extensive development of unit, technological and general functional specialisation. A far from easy problem in the foreseeable future is to overcome this inertia and markedly to advance specialisation.

The second reason, which is closely connected with the first, is the *extremely small share of inter-sectoral production lines.* The result is that most major engineering plants have preparatory shops, like foundries, forging and pressing shops, etc., which employ an estimated 11-12 per cent of all workers. Because a sizable part of these shops do not have optimal loading, they frequently fail to provide room for the operation of highly productive casting and forging machines.

In 1970, according to published data, the share of output by specialised enterprises and shops turning out parts and units of machines in a centralised manner (unit specialisation) came to 9.5 per cent in instrument-making, 8 per cent in heavy engineering, 5.2 per cent in road-building, 2.5 per cent in machine-tool making, and 1.2 per cent in chemical petro-engineering. The figures are even lower for enterprises and shops performing individual technological operations (technological specialisation). There were none at all in the making of road-building machinery and of machinery for the light and food industry, and only 0.2 per cent in machine-tool making, 0.6 per cent in tractor and farming-machinery making, and 5.3 per cent only in automobile-making.

The third reason, also connected with specialisation, is *the inadequate unification and normalisation of machine units and parts*, and this is true even for the individual ministries. Like inter-sectoral lines of production, inter-ministry general engineering unification and normalisation has up to now been developing very slowly.

An essential factor slowing down the growth of efficiency in engineering production is *the inadequate development of the specialised tool industry, and in particular, of the specialised manufacture of technological rigging.*

Over 90 per cent of the tools and instruments are turned out by over 4,000 tool shops at industrial enterprises, where labour productivity is about 60 per cent lower and the cost several times higher than at specialised plants of the tool-making industry,

At present, there is the task of consistently putting through radical changes in the organisational and technological structure of engineering production through the development of specialisation. This raises the problem of selecting the organisational and structural model for the development of engineering itself: is one to set up complex plants with a universal set of processes and shops and with powerful preparatory shops (foundries, forging and pres-

sing shops) and a set of powerful ancillary shops (including tool shops) or is one to look to the establishment of plants with a technological and unit specialisation and assembly plants cooperated with them and turning out the finished machines.

Of these two alternatives, I think, the scale and diversity of Soviet engineering suggest that it would be more effective and profitable to opt for an organisational and structural model oriented on the extensive development of plants with technological and unit specialisation and cooperated with specialised assembly plants.

The only serious objective and psychological impediment here (and one which will be widely met with in practice) is the lack of a tradition of scrupulously meeting the deadlines for cooperated deliveries. But the planned socialist economy can and must overcome this obstacle.

There is a need for a resolute and consistent line in building strictly specialised plants to turn out castings, forgings and punchings, fasteners and parts of general engineering application, plants for the manufacture of tools and rigging, and plants with product specialisation.

The inadequate development of production and the finishing and hardening of the final product (that which in metallurgy is called the fourth conversion) is a shortcoming in the structure of most industries. This necessitates an increase in the production and build up of the sectors engaged in the finishing, improvement of quality and the working specifications of the product. This applies to the finishing and thermal hardening of rolled metal, the drying and chemical impregnation of timber, hardening operations in engineering, development of finishing operations in engineering, the textile industry, and so on.

An important structural problem before the Soviet economy is the need to overcome the still sizable lag in the development of the infrastructure of material production: the industries which do not turn out material goods, but which provide services for the whole of material production (long-distance electric transmission lines, water supply, all types of transport communications, storage and packaging, and the system of enterprises providing services for production, technical and organisational backing).

In modern production, with its much more complex inter-sectoral ties, the very much larger scale on which

masses of the objects and products of labour are moved about, the infrastructure has an exceptionally great influence on the productivity of social labour, the costs of production, and the speed of assets turnover.

Those are some of the problems arising from the need to improve the structure of industrial and material production as a whole, problems whose solution is an important condition for realising the potentialities of the STR.

Substantial advances in the development of the USSR economy were made during the 10th Five-Year period (1976-1980). "In the years of the Tenth Five-Year period", the CC CPSU Report to the 26th Party Congress says, "the productive forces of the Soviet society have attained a qualitatively new level. The scientific and technical revolution is developing in scope and depth, changing the very appearance of many lines of production and whole industries. Soviet scientific research occupies a position of leadership in vitally important areas of knowledge.

"Through the past decade there were persistent efforts to enhance the efficiency of the national economy. The most concentrated indicator here is the productivity of labour. It rose during this period nearly 50 per cent. Scientific advances served as a basis for the further development or establishment of the most advanced industries, such as nuclear engineering, space technology, laser technology, the production of artificial diamonds and other new synthetic matirials. . ."

Those are some of the data showing the progressive structural changes which occurred in the 9th and 10th Five-Year periods in the sphere of material production.

4. ORGANISATIONAL PROBLEMS OF SCIENTIFIC AND TECHNICAL PROGRESS

Organisational conditions and factors also have an important role to play in the development and functioning of social production and, accordingly, in the development and realisation of the potentialities of scientific and technical progress.

Once the production resources—the means and objects of labour—have been allocated, the techniques decided

upon and the necessary personnel selected, it is a function of production organisation to turn these elements into a functioning production system which makes the most rational and efficient use of them. Production resources determine society's potentialities. Their realisation and use, the efficiency of social production crucially depend on its organisation. Economic practice in the USSR shows that the complexity and significance of organisational factors directly depend (and this tends to increase in a non-linear way) on the growth of the volume and complexity of the system being organised, and on the scale and complexity of the goals and tasks which it is designed to attain.

The process of organisation[1] is closely connected with the functioning of various systems (production system and others set up by men). Organisation is a necessary condition for transforming an aggregation of elements into a functioning system. It starts from the goals set before the system and is expressed above all in the grouping of the latter's elements—the formation of the means of production and workers—into a definite purposeful structure and the establishment of the necessary inter-relations and inter-action among them. This means a balanced combination in space and time of the joint labour of producers with the material elements of production.[2]

At the enterprise, the primary unit of production, production organisation is expressed in the following: division of labour, specialisation and cooperation of shops and sections; arrangement of the means of labour, the points of control and storage in space; the formation and function-

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[1] The term "organisation", I think, has two aspects: state and activity. In the broadest sense, the organisation of social production is the mode of production (the politico-economic meaning), which is determined by the way in which workers and the means of production are combined, and also by the relations between the participants in production over the property in the means of production, an aspect which lies outside the framework of the book.

[2] Organisation of production, seen as worker activity, is one of the key functions of production management. The latter includes, alongside the effort to organise production and labour, the working out of an optimal organisational structure of production proper and the services for managing production, administrative activity in the direct management of the process of production at the corresponding level.

ing of a definite system of services for production and, accordingly, specialisation and structure of ancillary services; a definite time schedule for realising all the intraproduction and external ties and the movement of production in time. The organisation of labour, a key component in the organisation of production, is the effort to ensure optimal working conditions and efficiency of work and their best combination with the production environment. This complex also includes the maximum easing of labour processes and an effort to make them creative; the selection and introduction of rational and efficient work methods; the use of the most rational systems of payment; the shaping of the right "climate" to stimulate the creative activity and high efficiency of workers.

On the level of industry, complex of industries and material production as a whole organisation of production covers the sectoral structure of production, specialisation and cooperation, and, accordingly, concentration of production; the system of intersectoral and territorial ties; the territorial location of production and the structure of territorial-production complexes; and the infrastructure and the whole system of services for material production.

Thus, *the organisation of production and labour, which determine the use of all the production resources, is the most important condition of efficiency, necessary component of the intensification of production.*

Under the socialist relations of production and organisation of production there must be an expression of the process leading to a steady rise in the level of socialisation of production and labour. In his work, *The Immediate Tasks of the Soviet Government*, written after the nationalisation of industry, transport, the banks, etc., Lenin said that the most important and central task was to socialise production in practice,[1] this being connected, in his view, with specialisation of production.

Lenin believed that the process of socialisation does not stop and is not completed with the establishment of socialist property. It proceeds within the framework of that property and promotes its progress and improvement. It is expressed in the growing concentration and enlargement of

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[1] See V. I. Lenin, *Collected Works*, Vol. 27, p. 241.

the means and scale of production through its specialisation and combination; in the enlargement and concentration of the subjects of economic activity; in the orientation of each unit of social production upon complete and all-round consideration and effective satisfaction of social requirements; in giving priority to the socialist consumer both in articles of consumption and means of production; and in the imperative and optimal combination of one's "own" and national-economic efficiency of production.

With the level attained in the development of the productive forces in the USSR, specialisation and concentration can assume two forms: sectoral and regional, both being expressions of the growth of socialist socialisation. But with the steady improvement of modern production and complexification of its inter- and intra-sectoral ties, both forms may result in undue emphasis on departmental and local interests (the former in sectoral concentration, and the latter in regional concentration). Consequently, the organisation of socialist production needs to be oriented in a definite way. The main line of this orientation is to ensure the steady growth of the efficiency of social production.

This should not be reduced to the input-output ratio for each producer. A key characteristic of efficiency is the extent to which the system attains the main goal for which it has been or is being set up, namely, the most economical satisfaction of that unit of social requirements for which the system has been set up and is functioning.

What are the main lines in improving the organisation of production that are common to many different industries? At present the lag between the real process of socialisation behind the growth and complexification of social production can be traced. I believe that the need to overcome this lag is the primary and general problem in improving the organisation of social production in the 1980s and 1990s.

The present stage in the development of the Soviet economy, the vast resources of socialist production built up by the Soviet people over the sixty years of socialist construction, and the even greater tasks in building the material and technical basis of communism require a new and higher stage and level of concentration of production. That will

also be a higher level of socialisation in practice, as Lenin pointed out.

The first thing to emphasise is the need to consider the concentration and specialisation of production as an organic whole, and also their combination. The concentration of production is frequently identified with the enlargement of enterprises as expressed in the number of persons employed, volume of fixed production assets, and value of the product.

In present-day conditions, this approach is erroneous. Concentration should be seen as economically justified only when concentration involves *homogeneous products* or *homogeneous production functions*, (i.e., simultaneous specialisation of production) or all the stages in the processing of *homogeneous primary raw materials* (i.e., simultaneous combination).

In the age of the STR and specialisation, which is organically connected with it, the very concept of "concentration" calls for rethinking.

The establishment of tremendously large enterprises turning out a great number of diverse products and surrounded by all kinds of preparatory and service lines (sometimes very powerful) cannot, I think, be regarded as concentration of production, because this is, as a rule, economically unwarranted enlargement of enterprises which frequently reduces efficiency.

It is even less advisable to set up within the system of many departments all manner of small and medium-sized lines of production and service enterprises, basic and ancillary.

The whole of industrial practice in the second half of the 20th century shows that only a high level of concentration involving the production of homogeneous products or production services creates the conditions for truly revolutionary technical solutions. If electronics had developed within the entrails of each industry using it, and had not spun off into a highly specialised industry, it would still be mainly using cumbersome tubes, and would not have gone on to printed and then to integrated and large integrated circuits.

Diverse lines of production set up beyond the framework of the industries to which they would be truly basic, even if the most modern hardware is used in the process of their

construction, as a rule eventually turn out to be less efficient than specialised lines of production. Functioning within the framework of what is essentially an alien consumer industry, they tend increasingly to lag behind technical progress and standards of production in their proper industry.

The scattering of production lines hampers, among other things, the extremely important and necessary unification of structural units and parts with a similar functional purpose. The absence of specialised production of standardised and unified parts and units increases the need for spare parts, and increases the cost of repairs and operation of the machinery. The solution of these problems is a very complicated task.

Here are some other points. With the marked prevalence of sectoral management, the USSR economy at the present stage tends largely to develop along the way of building large-scale intersectoral territorial complexes, like the Tyumen oil and gas complex, the Baikal-Amur Railway, the Kursk metal-ore complex, etc. Because within the complex each industry is personified by the corresponding sectoral ministry, the latter goes on to build up "its own" servicing and ancillary lines: transport enterprises (naturally with repair facilities), production of structural materials, lumbering and wood-sawing, mechanical works, repair enterprises, etc. This has a negative effect on the development of specialisation and combination of production on the national scale and the development of the overall structure of the USSR economy.

It is no exaggeration to say that it is now absolutely vital resolutely to make a sharp turn towards specialisation (and towards combination, in some industries), as the only basis for the concentration of production in every sphere of the Soviet economy. Failure to solve these problems is one of the main reasons for the inadequate returns on the vast and steadily growing production resources which are at the disposal of the USSR economy.

Organisational problems have a key role to play in the steady advance of scientific and technical progress. The materialisation of scientific and technical progress is effected within the system of scientific establishments, design and development organisations, and directly in production. Consequently, the development and application of scientific and

technical achievements are organically connected with the interests of collectives and individual workers.

The key elements connected with the organisation and realisation of the STR in production are directly determined by the logic underlying the structuring and functioning of the mechanism of socialist-production management.

The first task of the management mechanism in this context should be the creation of conditions in which scientific and technical progress and its most rapid realisation become a vital necessity for every unit of the production and managerial hierarchy.

The structural unity of production, design, development (and also research in some systems) and the management of all these elements on the industry level evidently needs to be organisationally formalised, while the principles of economic calculus (profit-and-loss accounting) should operate unhampered within every unit and at every level of production.

The task of setting up economic-calculus production and scientific-production associations was planned for the Ninth Five-Year Plan (1971-1975), to include, alongside production enterprises, research, design and development organisations. This is the highest form of concentration and socialisation of production, creating the conditions for the elaboration and effective pursuit of a single technical policy and for accelerating technical progress. "The line of forming amalgamations and combines should be followed more boldly: in the long term, they must become the main units of social production operating on a profit-and-loss basis."[1]

This key organisational measure is aimed to achieve the greatest effect in realising the STR potentialities and enhancing the efficiency of production on that basis.

A resolution adopted by the CPSU Central Committee and the USSR Council of Ministers, "On Some Measures for Further Improving the Management of Industry" (1973), said that in setting up amalgamations and improving management one should "start from the need to raise the level of concentration of production of the basic products in the industry, development of the scientific and technical facilities, specialisation and cooperation of the enterprises merged on the basis of an organic combination into integrated eco-

[1] *24th Congress of the CPSU*, p. 82.

nomic complexes of production, research, design and development organisations for the purposes of bringing about a marked growth in labour productivity, improving product quality, cutting costs and improving other technical and economic indicators."[1]

In the Tenth Five-Year Plan (1976-1980), the task was set to complete the establishment of amalgamations in accordance with the general management schemes. The tasks have been set to elaborate and introduce general management schemes and to go on to a two- and three-tier system of management in building, and also to develop inter-collective farm, collective-farm and state-farm and state-and-cooperative associations, and agro-industrial complexes for the production, processing and sale of farm produce.

The gradual limitation of the system of fund supply and a switch to wholesale marketing of the means of production and securing the reserves of the means of production should be an important organisational condition for accelerating scientific and technical progress.

The setting of scientifically-grounded prices for new machinery is an important element in scientific and technical progress and realising its achievements in production.

Prices are the socialist state's powerful instrument of economic management. Planned price-formation makes it possible to exert a purposeful influence both on scientific and technical progress and the realisation of its results in social production.

The *steady reduction in the cost and*, accordingly, *in the price of production-capacity unit* (or unit of effect) is evidently a general uniformity of scientific and technical progress and, simultaneuosly, one of the key criteria of the efficiency of new technology.

The correct use of economic instruments like economic calculus, profit, credit, and various forms of material incentives, including material-incentives funds, has a great effect on technical progress.

Improvement of centralised planning of scientific and technical progress and all its echelons has a substantial and primary role in accelerating scientific and technical progress. Long-term plans are the leading element of this planning,

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[1] *Party and Government Resolutions on Economic Matters (1972-1973)*, Vol. 9, Moscow, Politizdat Publishers, 1974 (in Russian).

and they are an organic part—a division—of the consolidated state economic plans.

Of course, all this planning of scientific and technical progress is very complicated and calls for further improvement.

Improvement of the organisation of management of the economy and its individual units is among the key organisational conditions for accelerating scientific and technical progress and effectively realising the potentialities of the STR.

The socialist economic system opens up exceptional potentialities for creating and using the most progressive organisational forms of management.

CHAPTER SIX

THE FUTURE OF THE STR

We have examined the impact of the STR on the main functional elements of social production, and this enables us to give a characterisation of the modern—fourth stage, according to our classification—in the development of large-scale machine production, which has been taking shape since the middle of the century and which will evidently be the definitive one until at least the end of the 1980s.

1. THE MAIN FEATURES OF THE PRESENT STAGE OF LARGE-SCALE MACHINE PRODUCTION

In Chapter Two, characterising the third stage in the development of large-scale machine production, I said that some elements brought about by the STR—the initial stages of automation, polymer chemistry, etc.—began to appear and were applied even before the Second World War. At the beginning of the second half of this century, and even more so in the 1960s and since then, large-scale machine production began sharply to differ in scale and technical level from pre-war production. Although many features of the third stage continue to prevail in the fundamental principles of technology, this production is based on facilities which have an immensely greater sum-total and—most importantly—per-unit capacity. Industries and sections of production realising the potentialities of the STR have attained sizable, even if not prevalent, scale.

One need merely give a few figures. In 1977, the USSR turned out 3.3 million tons of plastics and synthetic resins,

1,088,000 tons of chemical fibre, almost 800 automatic and semi-automatic lines only for engineering and metal-working, 6,300 programme-controlled machine-tools, 2.8 billion rubles' worth of modern computing facilities, etc.

The definitive characteristic of the fourth stage in the development of large-scale machine production is *the preservation and weighted prevalence of traditional technology characteristic of the third stage in existing production, with the presence of large blocks of production apparatus and technology in which the STR achievements have already been realised.*

A gradual introduction and adaptation of the new, under the cover of the prevalent blocks of the traditional, are a key characteristic feature of the present state of material production in all the developed countries of the world.

Let us note that this coexistence is not expressed in a parallel or independent movement of the old and the new: it is active. Just as synthetic vessels and organs introduced into the human organism are gradually overgrown with living organic tissue, so in modern production the new grows into the traditional and is integrated with it in the most diverse forms. This splicing and integration is the specific feature of the present stage and that is what, I think, makes it a special (fourth) stage in the development of large-scale machine production.

These processes will be clearly discerned in all the basic elements of production.

In power engineering, there is a rapid growth of atomic-power stations and the initial development of breeder stations[1] with an unquestionable prevalence (and over a very long term) of thermal-power stations working on mineral fuel and hydro-power stations, and also with the preservation of the traditional technological cycle in the generation of energy.

In the instruments of labour, there is the multiplication of the unit capacity of technological aggregates with the preservation, in the main, of the traditional principles on which they are based; the rapid growth of automation and especially of its flexible forms: programme-controlled machine-tools, with the preservation of the prevalent role of the non-automatic cycle work in discrete-process industries; the ever broader use of optimisation of production by means of

[1] On fast neutrons.

electronic computers (mainly in continuous-process industries), but without a massive switch to a system of all-round automation of production.

In the *objects of labour*, there is the priority growth in the manufacture and introduction of polymer materials, with a simultaneous continued growth in the production and use of traditional structural materials[1]; the growing combination of polymer and traditional materials (polymer coatings, the treatment of wood by resins, etc.); the extensive improvement of the qualitative characteristics of traditional materials on the basis of the achivements of solid-state physics, the rapid introduction of synthetic materials into the making of consumer goods, with a continued prevalent role for the traditional raw materials of agricultural origin.

In *technological processes*, while some fundamentally new processes are developed and introduced, traditional methods continue to prevail, and they are being improved through all-round intensification with the use of high pressures, temperatures and speeds, and also blast energy, broad introduction of catalysts, accelerators and stimulators, reduction in the share of cutting processes and their extensive replacement with plastic deformation methods; more extensive use of chemical methods; and spread of continuous technological processes.

In *data processing*, there is a very rapid development of computers and allied hardware. But the experience of the 1960s and the 1970s does not suggest that even in the 1980s automated control systems will spread extensively beyond the framework of some lines of production as actual controllers (and not merely data-processing devices).

In *transport and communications*, there is a marked improvement of traditional facilities expressed in the much greater speeds of travel by all types of transport and greater capacity of communication channels, with a simultaneous introduction of some STR achievements, like video phones,

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[1] In 1977, the world produced 50 million tons of plastics and synthetic resins and 677 million tons of steel, 13.4 million tons of chemical fibres and 14.2 million tons of cotton fibre. In 1980, the USSR plans to turn out 5.4-6.0 million tons of plastics and synthetic resins and 160-170 million tons of steel, 1.45-1.5 million tons of chemical fibres and at least 9 million tons of raw cotton.

communications satellites, and the prospect of using lasers, holography, etc.

A general characteristic feature of this stage is the most extensive and ever accelerating introduction of modern facilities, information and communication devices in the non-production sphere and services.

Such are the basic features characterising the present stage in the development of large-scale machine production and evidently the basic potentialities for realising STR achievements until the end of the century.

That is a law-governed trend in the correlation between the stage in the development of large-scale machine production and the STR stage which run in the same period, but there is no straightforward identity between their characteristics. In material production, large blocks of traditional machinery and processes remain. At the stage we are considering, the potentialities of the STR are just being put to use in production, and they will be fully brought out when all the potentialities of the traditional facilities are exhausted, i.e., at the next, fifth consecutive stage in the development of machine production.

I think that the STR potentialities which are now obvious and which have been translated into technical terms will evidently come to prevail in material production at the end of the 20th and the beginning of the 21st century.

Accordingly, when analysing the trends and looking into the future, one has to consider two interrelated prospects: first, the trends and characteristics of the next, fifth, stage in the development of large-scale machine production at which the technical achievements of the current STR will become prevalent; second, the trends and characteristics of the next stage of the STR itself, whose content, I think, is so important that it could be seen as a new and future scientific and technical revolution that is more or less foreseeable at present.

2. STAGE IN LARGE-SCALE MACHINE PRODUCTION AT WHICH STR POTENTIALITIES WILL BE REALISED

The complete realisation in production of the foreseeable potentialities of the current STR will signify a tremendous qualitative advance in all the characteristics of social production.

One of its key characteristics, I think, is the *approximation to energy abundance.* I say "approximation", because there is no certainty that in this period the problem of the extensive generation of thermonuclear energy will be solved. And this may result in a situation in which the energy industry, despite its tremendous and continued growth, could remain a constraint on the development of production, because energy is the material condition of the solution of almost every problem in the development of present-day production. What will remain an indefinite magnitude above all is the possibility of the commercial use of thermonuclear energy.

It could provide the basis for achieving energy abundance because the raw material for it is water, which is available in unlimited quantities in the World Ocean. Furthermore, the thermonuclear reaction produces virtually no radioactive pollution, for the end product of this reaction is harmless. Finally, thermonuclear energy can, in principle, be directly transformed into electric power with a relative efficiency of close to 100 per cent. In addition, the generation of electric power is vastly simplified.

Academician V. A. Kirillin told a general meeting of the USSR Academy of Sciences in November 1974 that the extensive construction of atomic-power stations based on fast-neutron reactors could be started after 1985, while the first commercial thermonuclear reactors could be built at the end of the century. Similar views have been expressed by Academicians L. A. Artsimovich, N. N. Semyonov, E. M. Velikhov and B. B. Kadomtsev.

In mid-1977, leading Soviet physicists—Academicians Velikhov and Eliseyev—reported in the *Bulletin of the USSR Academy of Sciences* (No. 6 for 1977) that the results of the work with the Tokamak system have confirmed the basic assumptions, ushering in the phase at which pre-reactor parameters of the plasma are being achieved and the basic engineering systems required for the reactor developed. They said: "The task now is to study reactor-parameter plasma and complete the elaboration of the scientific and technical principles of the Tokamak energy reactor." Soviet-American scientific cooperation in controlled thermonuclear synthesis has yielded a great deal for the solution of this problem.

In 1976, Dr. Kitner gave a report on controlled thermonuclear synthesis under the US programme, whose ultimate

goal is to include thermonuclear energy in the US energy balance by the beginning of the 21st century. The programme envisages three phases:

1. By 1985, to obtain and analyse the behaviour of hydrogen plasma with reactor parameters, carry out a thermonuclear reaction with a deuterium-tritium system with a positive energy output in the experimental reactor (TFTR).
2. By 1990, to start one or two experimental power reactors (EPR) with an electrical capacity of over 10 Mw.
3. By 2000, to develop a prototype commercial thermonuclear reactor, DEMO, with an electrical capacity of 500 Mw to demonstrate that commercial thermonuclear power is technically feasible, economically expedient and safe in terms of radiation.

This project also evidently starts from the assumption that the commercial use of thermonuclear power will begin in the United States only in the 21st century, that is, if the experience in the development of uranium power is taken into account, thermonuclear power could become a more or less prominent component of the world energy-balance closer to the middle of the next century.

Of course, when looking into the future one should not ignore other and even more extravagant energy potentialities. Many physicists now devote much attention to studying problems in non-stationary energy processes underway within the nuclei of the Galaxy. Thus, the explosion of quasars, whose size is comparable with that of the stars, produces more energy than hundreds of billions of stars. The general conclusion drawn by physicists is that there must be new types of energy in nature which are much more intensive than thermonuclear energy. These types of energy are manifested on a cosmic scale. The logic of science shows that new and intensive sources of energy are opened up as man penetrates ever deeper into the structure of matter, into ever smaller interstices of time and space.

Circumspection in assessing the future should not amount to conservatism. I was present at the discussion of the long-term prospects for the USSR's economic development (15-20 years), when the late Academician L. A. Artsimovich, a leading Soviet physicist, said: "If the leading physicists of the world had been asked in the 1930s about the prospects for the coming 15-20 years in the practical use of the achieve-

ments of physical science, hardly anyone would have suggested the atomic bomb for 1945 and the atomic-power station for the 1950s". At the same time, it is not right to ignore the fact that even today—at the beginning of the 1980s—atomic power (whose use in practical terms is much easier than the use of thermonuclear energy) accounts for only 10 per cent of the electric power generated in the most developed countries of the world.

That is why, when assessing the "morrow" of the STR, we have to orient ourselves over a fairly long term—until the mid-21st century—upon a combination of traditional (mineral-fuel and hydro-energy basis) power and atomic power, with a growing but not prevalent role for thermonuclear, solar, geo-thermal and wind energy and a gradual penetration into the substance and nature of other types of energy existing in the surrounding world. That is why it is so important just now to improve the technology and the relative efficiency of power generation.

The solution of these problems, together with the more extensive use of mineral-fuel deposits, the further development of hydropower, and the intensive growth of atomic power could provide a real basis for achieving an abundance of energy in the foreseeable future, regardless of when the problem of thermonuclear power is solved.

In the *instruments of labour* over the long term we have been considering, prevalence should go to the instruments of labour produced by the current STR. In this period, it will be possible to realise a sizable part of the social effect of the new technology. This will be expressed in the following concrete terms. The all-round mechanisation of all the sectors of material production, including agriculture, will be completed, providing a basis for eliminating all the arduous and monotonous manual labour.

All-round automation will cover the continuous lines of production—electric power engineering, metallurgy, oil refining, chemistry and other industries—those which most lend themselves to automated control, the use of modelling and controlling electronic systems, optimisation and the introduction of fully automatic production cycles.

Automation will also range broadly over the sectors with discrete processes and discrete products: engineering, woodworking, garment-making, etc. There will be extensive use here of equipment with programme control, something

that will largely help to solve the problem of stability of production and technology.

The technical re-equipment of agriculture will help to transform farm labour into a species of industrial labour.

Progress in the instruments of labour in the period being considered will release the worker from the need to act as a motive force and from the bulk of the work arising from the direct operation of working machines and tools. Mechanical and electronic devices will be intensively introduced into the processes of adjustment of mechanisms and production lines, and will be extensively used in the design and control of production. An intensive switch to continuous technological processes and chemical methods will markedly increase laboratory-type work.

The growing technological application of science in production will raise the skill standards of the bulk of the workers who will be increasingly involved in monitoring the numerous complex instruments and devices recording (and partially regulating) the operation of technological equipment. The extensive introduction of product-flow lines will require an increase in the share of multi-trade workers capable of handling a broad range of production processes.

The main functions of those working in material production will ultimately be adjustment and maintenance of automatic production lines in a working state, elaboration of programmes and control of machine systems performing processes whose automation is technically impossible or economically ineffective.

The extensive use of data processing facilities will make major changes in the nature and content of the traditional processes of mental labour. Computers will perform a sizable part of routine work, as men increasingly confine themselves to the creative types of work.

In this way, the conditions will be shaped for solving one of the basic social problems in communist construction, namely, elimination of the essential distinctions between mental and manual labour and a gradual merger of these functions in the process of social production.

With the extensive introduction of automation, the instruments of labour will have to produce a social effect not only in terms of the nature of labour but also in terms of the product. This is due to the fact that as society moves forward and men's cultural and intellectual standards rise,

a substantia contradiction tends to develop between the efficiency of mass production and the irresistible individualisation of the requirements and demand for its products.

This trend towards a growing individualisation of requirements does not in any sense contradict to the uniformities underlying the development of the socialist and communist society. As the requirements in consumer goods are individualised, there will evidently be an inevitable need to individualise the requirements in the means of production to some extent, something that will produce the same contradictory problem: the need to blend the advantages of mass production with the output of the piece produced and increasingly individualised product.

The technology produced by the STR helps to overcome this looming contradiction as well. Thus, programme-controlled machine-tools and other automated equipment, combined with electronic programmed control of intra-plant and intra-shop transport facilities (conveyers) will help easily to switch the equipment to the manufacture of other types of products.

The use of computers will reduce to a fraction the time interval between the start of design and development and the actual manufacture of the product. They will not only design parts and whole articles, but also read off blueprints of components and automatically recommend the way of production of these articles. Their mass use at every level of production and control will help to cut overheads and give engineers, technicians and managers the time to tackle creative problems. The automation of production and the use of cybernetics will make it possible to run production processes at optimal regimes, and this will not only help to save on living labour, but also to make better use of the equipment, raw and other materials, intermediate products, etc. All of these are important components of the efficiency of social production.

A sophisticated information industry and information infrastructure will be developed. These will consist above all of data processing systems for a broad range of collective and individual users which is required for every unit of social production, for research and technical development, for automated systems of planning and control of production and of the whole economy in its various spheres and at various levels.

In the *production of materials*, this stage will be characterised above all by a marked increase in the share of polymers. Polymers already have a very important role to play in every sector of the economy. The writer Boris Agapov has aptly described their role: "If all the synthetics on the globe were suddenly to be depolymerised, all the planes would have plumped to the ground, all the telephones would go dead, the radio and television sets would burn up, monstrous accidents would occur on the railways and in all the places where automatic regulation and safety devices are in operation... The chief element in modern society's nervous system is not metal, but insulation. Mankind's life would be in mortal danger."

There is every reason to assume that in this period the output of plastics will come very close in volume to the output of steel, and may possibly surpass it. That is one of the key characteristics of this stage in the development of machine production.

Over the long term we have been considering, the mass production of silicon-based polymers will also evidently be organised. Advances in the study and industrial use of super-conductivity and cryogenics will lead to the practical use of super-conducting materials, and this entails radical changes in some industries, especially the electric-power and electro-technical industries.

According to published data, the use of super-conducting materials and cryogenic devices will make it possible to reduce, by the end of the 1980s, the size of electric machines by 30-40 per cent, and their weight by 80-90 per cent; almost 25 per cent of all new electric machines will be of the cryogenic type, and this will yield tremendous economies.

Advances in solid-state physics and its main lines will result in large-scale production of high-durability structural materials with a unique set of mechanical and other physical properties. Practical use will be made of new materials, including magnetic materials, with fundamentally new properties that are required in various technical fields.

Traditional materials will undergo considerable changes and improvements. The strength of steel and many alloys will be multiplied many times over. Specialists estimate that by the end of the 1980s, the strength of carbon steels will go up from 25-35 kg/mm^2 to 50-70 kg/mm^2, of low-alloy steels from 20-50 kg/mm^2 to 80-130 kg/mm^2, and high-alloy

steels from 130-150 kg/mm^2 to 450-600 kg/mm^2. This will make it possible markedly to reduce the weight of metal structures and sharply reduce the relative demand for ferrous metals, a fact that will substantially enhance the efficiency of social production.

A survey of projects already underway in scientific institutions and laboratories shows that in the period under consideration super-plastic alloys will be developed and broadly applied, resulting in a considerable reduction in inputs into their treatment.

Combined materials (plastics and light metals) will be important items in fields where steel is traditionally used, and also rolled steel with plastic coatings.

Thus, the observable trends in the production and use of the objects of labour will help substantially to reduce the material-intensiveness of production. The range of structural materials will also develop in the same direction. The industries turning out basic materials will increasingly handle primary shaping, and this will be expressed in an extension of the assortment, an increase in the output of intermediate products, and blanks with minimum discrepancies from the dimensions required by customers, so obviating the need for any further treatment.

Polymer materials will account for a much greater share of the fibrous-materials balance.

There will be intensive advances in improving the quality characteristics of foodstuff raw materials, and in particular, those of agricultural origin. Successes in selection and genetics make it possible, given a sharp increase in crop yields in agriculture and productivity in stock-breeding, markedly to increase the content of nutrients in a volume unit of cropping and stock-breeding products. That is one of the key lines in intensifying production in agriculture and the food industry.

Over the period we are considering, extensive use will be made in industrial practice of the existing STR advances in the field of *production techniques.*

The previous chapter described the potentialities of chemical, electro-chemical and laser processes. There will be extensive application of machine systems making use of all these potentialities. The use of automated, technological, transport and moving machines, adaptive-control systems and computers will make it possible to develop automated

techniques even in industries with discrete processes and products, notably engineering.

Over the period, *agriculture* will be fully industrialised. Extensive use of satellites and space rockets to combat natural calamities will make agriculture much less dependent on the weather. Electrification and the use of chemicals, together with selection and genetics, including the initial stages of genetic engineering, will become an organic part of agricultural production. The main operations, especially labour-intensive ones—ploughing, sowing, harvesting, sorting and delivery—will be subjected to all-round mechanisation, and wherever possible, automated. All-round mechanisation, extensive automated production and, wherever appropriate and possible, automated regulation of all production processes will be introduced into stock-breeding.

Those are the key characteristics of this stage of large-scale machine production in the USSR.

These potentialities are not only of technico-economic but also of major socio-economic importance.

The energy resources and potentialities of this stage, the future progress in the instruments and objects of labour, and also in methods and organisation of production evidently create all the necessary material prerequisites for ensuring high and stable output rates, for markedly enhancing the social effect of production and bringing about stable growth of economic efficiency, i.e., for developing material production capable of tackling the tasks in building the material and technical basis of communism, achieving an abundance of products and fulfilling the main social tasks of communist construction. At the same time, a major stride will be taken in the economic competition with capitalism. The socialist system will demonstrate its fundamental advantages over capitalism.

3. THE "MORROW" OF THE STR

The potentialities of the STR are realised in the economy and its sectors; economic conditions determine the lines along which these potentialities are realised. Society, which exists within the framework of definite relations of production, takes decisions on which the progress of science and production depends. In this book, alongside the analysis of the ways of tackling the economic problems of the scientific

and technical revolution in the USSR, a country of mature socialism, there is consideration of the economic aspects of the STR common for industrially developed countries of the world.

Up to now I have tried to characterise the origins, formation and development of the present STR, its material content, main spheres and visible socio-economic results and consequences.

The Marxist analysis of the trends in the development of the material productive forces, and a study of the logic underlying the development of the natural sciences and scientific and technical progress on the whole make it possible to conceive the main lines, the main contours of the "morrow" of the STR, or it would probably be more correct to say, of the next scientific and technical revolution.

What I described in the previous chapters—the processes going forward in the natural sciences, the trends in the change and development of the basic elements of production under the impact of the STR—reveal the contours of scientific and technical progress and material production over the foreseeable future. But before going on to a description of this "morrow" there is a need to determine one's attitude to the highly broad discussions about the present and the future of material production, scientific and technical progress and human life on Earth generally, discussions which are being carried on in broad scientific circles and government agencies concerning real and visible facts and processes.

In the context of the problems analysed here, the following dilemmas arise: should one seek to advance the STR or is one to shy it? Should one give thought to using all its potentialities for further economic growth or is one to limit such growth and development in order to safeguard mankind from the allegedly looming disaster? Should one ultimately give thought at all to the lines for mankind's further growth, of its living standards, living conditions and well-being, or should one concentrate attention on the limits to such growth?

These and many other dramatic dilemmas have arisen in response to the crises which, entwined with each other, have recently shaken the world and caused growing apprehension among all thinking people. One need merely mention the so-called population explosion, the energy, ecological and food crises, against a background of galloping inflation

and unemployment in the leading capitalist countries. As a result, broad circles of world opinion were confronted in the 1970s with the acute and burning problem of "limits to growth".

In 1970, the Club of Rome, a non-governmental organisation of scientists, industrialists and public figures, decided to put through a project entitled "Man at the Crossroads". The study was first carried out by the Department of Systems Dynamics of the Massachusetts Institute of Technology headed by G. W. Forrester. Its purpose was to analyse the most meaningful problems facing mankind: population growth, food resources, poverty, worsening environment, etc. Forrester produced an initial model of the world reflecting the interconnections between the problems formulated by the Club of Rome. It was elaborated by an inter-disciplinary group led by Professor Dennis L. Meadows. The results of the first stage of the study covered five basic factors: population, capital, food production, depletion of natural resources, and pollution of the environment. They were published in 1972 in a book entitled *The Limits to Growth*, presented as the First Report to the Club of Rome. Its authors were the Americans Donella H. Meadows, Dennis L. Meadows, Jorgen Randers, William W. Behrens III. It sparked off a lively discussion, and in 1973 a research group on science politics at Sussex University in Britain produced a work entitled *A Critique of Limits to Growth.*

In 1974, came the publication of a book by Mihajlo Messarovic (USA) and Eduard Pestel (FRG) entitled *Mankind at the Turning Point. The Second Report to the Club of Rome.* It dealt with "future generations" and the epigraph to Chapter One, entitled "Prologue: From Undifferentiated to Organic Growth" was a quotation from A. Gregg[1]: "The world has cancer and the cancer is man."

The Third Report to the Club of Rome, entitled *New Economic Order*, was published in 1975. Its authors, the Norwegian economist Jan Tinbergen and his colleagues, put forward the problem of changing the present economic system of capitalism in order to reduce the inequalities in the living conditions of peoples in developed and developing countries.

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[1] See "A Medical Aspect of the Population Problem", *Science*, No. 121, 1955, p. 681.

In 1976, the Milan publishers Mondodori published the Fourth Report to the Club of Rome entitled "Beyond the Age of Waste" edited by Nobel Prize winner D. Gabor and W. Colombo. That same year, Herman Kahn, director of the Hudson Institute in the United States, together with associates William Brown, and Leon Martel, published a book entitled *The Next 200 Years*. Among other works let us also mention *Disaster over the New Society*, a book by A. Harrar and other Argentinian authors published in Canada in 1976.

It is impossible here to present the content of these works, but they will be used to clarify various matters relating to the present and future of the STR.

The meaning of the First Report to the Club of Rome, which sparked off the discussion in 1972, consists in an analysis of the physical limits to the growth of population and material production, rather, to mankind's material activity on the planet Earth, if the exponential nature of their dynamic is maintained.

The leaders of the Club of Rome, Aurelio Peccei and Alexander King, said in their commentaries on the Second Report, that "Professor Dennis Meadows and his team projected into the future a number of interacting critical phenomena with a view to indicating what might happen to the world systems if present trends were allowed to continue."[1]

The authors of *The Limits to Growth* say that advances in medicine and the growing production of foodstuffs have increased the average life-span from 30 years in 1650 to 53 years in the early 1970s. They say: "Unless there is a sharp rise in mortality, which mankind will certainly strive mightily to avoid, we can look forward to a world population to around 7 billion persons in 30 more years and in 60 years there will be four people in the world for every one person living today."[2] Let us note that these magnitudes have been substantially overstated. A four-fold growth over 60 years comes to an annual rate of 2.3 per cent. In actual fact, according to statistics, the rate has been on a fairly stable down-

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[1] Mihajlo Mesarovic and Eduard Pestel. *Mankind at the Turning Point. The Second Report to the Club of Rome*, Hutchinson of London, 1975, pp. 201-202.

[2] Donella H. Meadows, Dennis L. Meadows, Jorgen Randers, William W. Behrens III, *The Limits to Growth*, Pan Books, London and Sydney, 1975, pp. 37-38.

grade, and from 1971 to 1977 came to 1.9 per cent. But even if this rate is maintained, the population of the world by the year 2000 will come to about 6.4 billion, and within 60 years will have increased not four-fold but 3.2-fold.

The authors then go on to predict a shortage of fertile lands: "Even with the optimistic assumption that all possible land is utilised, there will still be a desperate land shortage before the year 2000 ... there has been an overwhelming excess of potentially arable land for all of history, and now, within 30 years... there may be a sudden and serious shortage".[1] The authors estimate that the costs of developing new lands or raising crop yields on already cultivated lands will tend steadily to grow. "We might call this phenomenon the law of increasing costs."[2]

They predict a similar problem with fresh water, and regard its looming shortage as yet another possible limit to the production of food.

They present an equally dark prospect in the sphere of resources for obtaining production materials whose depletion, they say, will occur in the foreseeable future. Finally, they project exponential growth in the pollution of the biosphere, both in terms of the waste from the combustion of fuel (carbon dioxide CO_2 and carbon monoxide CO), pollution with radio-active waste and—a new and very important element—"thermal pollution", connected with the growing production and consumption of energy.

"We might estimate," write the authors, "that if the 7 billion people of the year 2000 have a GNP per capita as high as that of present-day Americans, the total pollution load on the environment would be at least ten times its present value. Can the earth's natural systems support an intrusion of that magnitude? We have no idea. Some people believe that man has already so degraded the environment that irreversible damage has been done to large natural systems. We do not know the precise upper limit of the Earth's ability to absorb any single kind of pollution, much less its ability to absorb the combination of all kinds of pollution. We do know however that there is an upper limit. It has already been surpassed in many local environments."[3]

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[1] *Ibid.*, p. 51.
[2] *Ibid.*, p. 53.
[3] *Ibid.*, p. 84.

In the context of industry, the authors predict that "each unit of industrial output consumes some non-renewable resources reserves. As the reserves gradually diminish, more capital is necessary to extract the same amount of resource from the earth, and thus the efficiency of capital decreases."[1]

The authors computed a "type" variant of the world model which is based on the assumption that no historical changes will occur in physical, economic and social relations governing the development of the world system. All the presented parameters correspond to their real 1900-1970 values. They draw the following conclusion: "Food, industrial output, and population grow exponentially until the rapidly diminishing resource base forces a slowdown in industrial growth. Because of natural delays in the system, both population and pollution continue to increase for some time after the peak of industrialisation. Population growth is finally halted by a rise in the death rate due to decreased food and medical services.

"As resource prices rise and mines are depleted, more and more capital must be used for obtaining resources, leaving less to be invested for future growth. Finally, investment cannot keep up with depreciation, and the industrial base collapses, taking with it the service and agricultural systems."[2]

The authors believe that growth will slow down much earlier than the year 2100.

These apocalyptic prospects naturally suggest to the reader that perhaps the STR, which has produced many of the elements of this prospect, may also offer strong and effective means for averting these phenomena or neutralising them. Above presented many facts and considerations suggest that this is so. Below I shall try to consider them in the light of the reports to the Club of Rome.

The authors do not ignore technical progress. They have a special section in their report entitled "Technology and the Limits of Growth". They write: "Since the recent history of a large part of human society has been so continuously successful, it is quite natural that many people expect technological breakthroughs to go on *raising physical ceilings* indefi-

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[1] *Ibid.*, p. 101.
[2] *Ibid.*, p. 124.

nitely. These people speak about the future with resounding technological optimism... Our attempts to use even the most optimistic estimates of the benefits of technology in the model did not prevent the ultimate decline of population and industry, and in fact did not in any case postpone the collapse beyond the year 2100."[1]

Consequently, according to the authors, technical progress does not provide the means for averting the disaster they predict. "Is it better to try to live within that limit by accepting a self-imposed restriction on growth? Or is it preferable to go on growing until some other natural limit arises, in the hope that at the time another technological leap will allow growth to continue still longer... The first choice has been all but forgotten.

"Technology can relieve the symptoms of a problem without affecting the underlying causes".[2]

The authors proposed that a limit should be put to the growth of the population from 1975 on, and of capital, from 1985 on. The minimum set of requirements for a state of equilibrium, they think, is the following:

"1. The birth rate equals the death rate and the capital investment rate equals the depreciation rate.

2. All input and output rates—births, deaths, investment and depreciation—are kept to a minimum.

3. The levels of capital and population and the ratio of the two are set in accordance with the values of the society."[3]

Because the volume of material production is basically fixed, any improvement in production methods could lead to an increase in leisure time for the population. "Technological advance would be both necessary and welcome in the equilibrium state. A few obvious examples of the kinds of practical discoveries that would enhance the working of a steady state society include: new methods of waste collection, to decrease pollution and make discarded material available for recycling; more efficient techniques of recycling, to reduce rates of resource depletion; better product design; harnessing of incident solar energy, the most pollution-free power source; medical advances, ... that would facilitate the equalisation of the birth rate with the decreasing death rate, etc." The authors end their conclusions

[1] *Ibid.*, pp. 129, 145.
[2] *Ibid.*, pp. 153, 154.
[3] *Ibid.*, pp. 173-74.

with the following statement: "Not blind opposition to progress, but opposition to blind progress."[1]

The Second Report to the Club of Rome starts from a different premise: "Mankind is at a turning point in its history: to continue along the path of cancerous undifferentiated growth or to start on the path of organic growth."[2]

This will result in creation of a new mankind. It will be a dawn, a beginning and not the end. The authors try to sort out the nature of the global crises and note two very important characteristics.

The first is that these crises are numerous, simultaneous and entwined with each other, which is why mankind does not have "*the luxury of dealing with one crisis at a time*".[3]

The second characteristic relates to the origins of the crises. In the past, the authors say, crisis originated only from *negative causes*: natural disasters, destructive acts by aggressive rulers, etc. The causes of the current crises are positive acts and originate from mankind's *best intentions.* The reduction of labour inputs through the use of energy resources led to the energy crisis; the strengthening of the family and advances in combating diseases and lowering the death rate led to the demographic crisis; the construction of hydropower plants and the development of industry led to the crisis of the environment. "The modern crises are, in fact, man-made",* the authors say, and draw the conclusion that these crises "differ from many of their predecessors in that they *can* be dealt with."[4]

The authors believe that the way to combat these crises is to go on to organic growth. "Now is the time to draw up a master plan for organic sustainable growth and world development based on global allocation of all finite resources and a new global economic system."[5] Characterising the values and principles of such growth, the authors emphasise the development of the consciousness of belonging to the

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[1] *Ibid.*, p. 154.

[2] Mihajlo Mesarovic and Eduard Pestel, *Mankind at the Turning Point. The Second Report to the Club of Rome*, p. 9.

[3] *Ibid.*, p. 11.

* We do not agree that the basic cause of the crises is that they are or are not man-made. All the crises of capitalism, be it the economic, demographic or ecological crisis, are rooted in the socio-economic contradictions of the capitalist system.

[4] Mihajlo Mesarovic and Eduard Pestel, *op. cit.*, p. 15.

[5] *Ibid.*, p. 69.

world community: a new ethic in the use of material resources; attitude to nature based on harmony instead of conquest; and a sense of identity with future generations.

Mesarovic and Pestel have good reason to include among the chief crisis problems a fair distribution of global world resources and, accordingly, a fair distribution of goods and services. Aurelio Peccei and Alexander King, who head the Club of Rome, write in their commentary on the Second Report: "How can a true world community emerge, or even our present human society survive when it is ridden by profound and intolerable injustices, overpopulation and megafamines, while it is crippled by energy and materials shortages, and eaten up by inflation? What explosions or breakdowns will occur, and where and when, now that nuclear war technology and civil violence are outrunning the pace of political wisdom and stability?"[1]

The authors seek to show the meaning of "organic growth" by drawing an analogy with the growth of the living organism. This analogy relates to the specialisation of the various parts of the organic system and the functional interrelation between its component parts, in the sense that none of these is self-sufficient, but has to fulfil the role assigned to it by historical evolution. In an effort to show the conditions for this highly necessary (in their opinion) "organic growth", the authors are unable to side-step the contradictions which are inherent in the capitalist system, with whose categories they have to operate.

In their preface they say: "Were mankind to embark on a path of organic growth, the world would emerge as a system of interdependent and harmonious parts, each making its own unique contribution, be it in economics, resources or culture."[2] They then go on to admit that there are some gaps in their report. "There will hardly be any mention of some crucial political problems resulting from increased military and ideological polarisations. This should not be construed as failure on our part to recognise the seriousness of such threats to the world community. Indeed, there is obviously no more effective short-cut to the destruction of mankind than an atomic war involving the superpowers and their respective military blocs. Even

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[1] *Ibid.*, p. 206.
[2] *Ibid.*, p. VIII.

barring such an event, we are convinced that the continuous escalation of armament in an effort to maintain the balance of power is steadily decreasing the stability of other equally delicate world balances."[1]

The efforts of the Soviet Union and all the socialist-community countries to strengthen the detente and make it irreversible, to bring about a reduction in strategic weapons, and a steady elimination of the monstrous arsenal of nuclear and other weapons, to arrange regional and world cooperation on the most vital problems in maintaining and consolidating peace, and for preserving and improving the whole environment of the Earth, all of these amount to an actual struggle for the sake of the "organic growth" which the authors of the Second Report so strongly advocate.

Mesarovic and Pestel reject the perspective outlined by the authors of the First Report and hope that the World Community they envisage, will be able to use the potentialities of technical progress, to align living conditions in various regions of the Earth and to ensure "organic growth" going well beyond the "limits" laid down by the authors of the First Report.

Consequently, the authors of the Second Report come close to the problem of setting up a different social system and formulating the conditions which are incompatible with capitalist relations of production, with present-day capitalism and the arms race which it engenders, the virtually uncontrolled operations by the transnationals, its ecological and economic crises and unemployment, neocolonialism and the conservation of colonial backwardness in some African, Asian and Latin American countries, etc.

The authors of the Third Report set themselves the task of substantiating the need for shaping a new international order, and give a circumstantial analysis of the conditions now existing in the world, which largely influence both further development and the realisation of the already available potentialities of the STR. They say: "The call for a new international economic order was made in a period of economic turmoil without precedent in the postwar world. The industrialised countries were experiencing economic

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[1] *Ibid.*, pp. XI-XII.

dislocation unknown since the agonies of the Great Depression of the 1930s."[1]

Vast masses of people, whole countries and virtually entire continents exist in conditions almost ruling out the possibility of their using STR achievements, to say nothing of their active participation in advancing science and technology. The countries of Asia (Japan apart) and Africa, which have 62.9 per cent of the world's population, turn out only 12.6 per cent of the world's GNP. Meanwhile, the countries of North America, Europe (without the USSR) and Japan, with 22.1 per cent of the world's population, turn out 71 per cent of the world's GNP. All the developing countries, whose population comes to 71 per cent of the world's total, account for only 18 per cent of the energy generated in the world. This is a monstrous inequality, which the developed capitalist countries seek to perpetuate and increase.

The period since the Second World War was marked by the rise to political independence by many national states. But, say the authors of the Third Report, "they discovered that political liberation does not necessarily bring economic liberation and... that without political independence it is impossible to achieve economic independence... This economic dependence is rooted in the main institutions of the international system created largely by the industrialised countries to deal essentially with their own problems at a time at which the voices of the world's poor were unheard in international fora... They contend that the 'free' market is in fact not 'free', but works to the advantage of the industrialised nations... because of their enormous political and economic strength."[2]

The figures presented in the Third Report show that far from being evened out, the inequality tends to grow and deepen: from 1913 to 1957, income per head (in dollars of the USA) increased: in North America by 104 per cent, in North West Europe by 74 per cent, in South-East Asia by 3 per cent and in China by 22 per cent. As a result, income per head in South-East Asia in 1913 was only 14 per cent of that of North West Europe and 7 per cent of North Amer-

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[1] *Reshaping the International Order. A Report to the Club of Rome.* Jan Tinbergen (coordinator), Anton J. Dolman (editor), Jan Van Ethnger, E. P. Dutton & Co., Inc., New York, 1976, p. 21.

[2] *Ibid.*, pp. 15-16.

ica's. In 1957, the figures were, respectively, 9 per cent and just over 3 per cent.

The authors of the Third Report say that today about two-thirds of mankind live on less than 30 cents a day. There are about 1 billion illiterate people around the world, although the world has the facilities to spread education. The number of people suffering from hunger and malnutrition comes to between 500 million and 1.5 billion; children make up 40 per cent of the world's population and 50 per cent of the population in the developing countries suffering from hunger, while the world has sufficient resources to feed them. A direct outcome of this, it is said, is stultified physical growth and development among more than 300 million children. As a result of the unfair distribution of the resources available in the world, the industrialised capitalist countries consume 20 times more per head than the newly-free countries. This is well illustrated by the state of food production.

According to the Third Report, in the 1950s the newly independent states increased food output per head by 0.7 per cent and in the 1960s by 0.2 per cent, or only 400 grammes per head a year, as compared with the developed capitalist countries' 11.25 kg per head, that is, nearly 30 times more. Over a period of two decades, the rise in incomes of two-thirds of mankind came to less than $ 1 per head a year.

Such is the condition of STR subjects over a sizable part of the globe, and such is the situation in many countries which are unable to realise STR achievements for the benefit of their peoples. Evidently, such a state of affairs must necessarily act as a great drag on scientific and technical progress now and in the foreseeable future.

The authors of the Third Report are aware that highly radical measures are required to change the order they describe. The current crisis of the capitalist world economy and relations between countries, they say, is a crisis of the international structure, a crisis which cannot be coped with by things like economic first aid. "What is required are fundamental institutional reforms.... Social mutations have sometimes taken the form of *revolutions*,"[1] as illustrated by the French, the Russian, the Cuban and other revolutions. Changes in the world order and structure, accelerated

[1] *Ibid.*, p. 21.

by STR processes, also turn out to be an important condition for the development and realisation of the STR. This makes them an imperative need. "Recent discontinuities in the process of change have placed mankind on the threshold of new choices. In choosing among them, it will have to accept the harsh fact that, perhaps contrary to previous times, it has just one future or no future at all."[1]

At the same time, the Tinbergen group take a sober view of the real attitude of the Western powers to the problems facing the liberated countries. They say: "It is certainly true that the majority of Western politicians are being driven to the world's negotiating tables, not by the plight of the poor nations, but by the plight of their own economies and by the serious dislocations in the international system which has helped make the wealthy nations wealthy. Hence their inevitable preoccupation with safeguarding the flow of supplies of raw materials and oil."[2]

The authors of the Third Report take a pessimistic view of the prospects for narrowing the gap between rich and poor. Assuming, they say, that income per head in the developing countries comes to about 5 per cent a year, and remains on the level of the 1960s in the developed countries (3.3 per cent), even with the lowest rate of population growth estimated by the United Nations, by 2012 the ratio of the incomes of developed and developing countries will come to 13 to 2, a clearly intolerable level making political stability impossible. The actual rates turned out to be even less favourable for the developing countries: from 1951 to 1976, national income growth for the developing countries came to 5.2 per cent, and for the developed to 4.1 per cent.

Although the Tinbergen group are not radically minded at all, when formulating their "strategy of change", they recommend to the developing countries measures like control over natural resources, control of foreign investments, and *solidarity* among liberated countries, "the greatest power which the Third World possesses.... Without it, it will prove infinitely more difficult to obtain major concessions from the rich nations".[3] Finally, they say that control implies the attainment of "intellectual liberation" for the

[1] *Ibid.*, p. 23.
[2] *Ibid.*, p. 47.
[3] *Ibid.*, p. 107.

developing countries and a reform of the information system: "Flows of information from the Third World to the industrialised countries are controlled by a handful of Western news agencies".[1]

The authors then set forth largely utopian proposals for a re-distribution of incomes, for financial, material, technical and food aid, proposals on disarmament and the use of the money going into armaments for the purposes of development. They end with these three most general recommendations: elimination of the blatant injustice in the distribution of incomes and equal economic opportunities for all; more harmonious development of the world economic system; and development of the beginnings of a world planning system. In conclusion they expressed the hope, that mankind will have the wisdom, the courage and the foresight to meet this supreme challenge.

Let us recall that the Soviet Union has made constructive proposals and presented programmes aimed to solve these complex problems at every international forum, including the 1978 UN General Assembly on Disarmament.

The Tinbergen group say: "Any country with a large nuclear reactor and access to facilities separating uranium and plutonium is a potential nuclear power... By the 1980s, the world's reactors will have produced about one million pounds of plutonium—enough to manufacture 50,000 explosive devices. And even if countries should prove wise enough not to manufacture nuclear weapons there is the growing danger that fissionable material will fall into the hands of political extremists and terrorist groups."[2]

The authors of the Fourth Report to the Club of Rome, a book entitled *Beyond the Age of Waste*, edited by D. Gabor, Nobel Prize winner in physics, and U. Colombo, published in Milan in 1976, impelled by the logic of research and the logic of development in the modern world, consider changes of a social order. They say: "We must exercise our creativity to produce social conditions for a mature society, no longer characterised by dependence on growth in resource consumption. The new society must provide a continued improvement in the quality of life, with harmony among peoples of different cultures, social classes, and individuals. To

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[1] *Ibid.*, p. 111.
[2] *Ibid.*, p. 26.

achieve these objectives institutions must be thoroughly reformed on national and international levels. Science and technology are invaluable instruments for coping with and solving the serious problems posed by the limited availability of resources. However, one must recognise that the present machinery of the economic system impedes the prompt tackling of certain serious and urgent problems. Problems related to the finite nature of natural resources are international. Their solution requires basic recognition that the regions of the world have become strongly interdependent and must be treated as components of a single system. Unfortunately, present political structures lack adequate decision-making mechanisms and institutional framework for managing global problems and their complex relationships within the world system. This also explains the difficulties in establishing and conducting large international cooperative efforts in science and technology."[1]

In Chapter Six, "Some Global Considerations", there is a paragraph on the problems of waste, and here the authors formulate their idea in more resolute terms: "Improved agriculture, through new research, cannot provide for a doubled world population unless there are fundamental changes in the economic and social system and in the international political thinking."[2] They also emphasise that the arms race, inflation, unemployment, mutual suspicion, and uncertainty in the future are obstacles to the creation of better living conditions for the peoples of the world.

The final, seventh, Chapter of the Fourth Report is entitled "Science, Technology and Institutional Implications". The authors clearly recognise the inadequacy of the social structures and social institutions existing in the developed capitalist countries to the potentialities created by the current STR. "While human capacity to shape the environment, society and human beings is increasing rapidly, policy-making capabilities to use these capacities remain the same."[3] They recall that the OECD Science Ministers pointed out in 1975 at their fifth meeting that "in the future, technology must be socially acceptable. This is easily said,

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[1] *Beyond the Age of Waste. A Report to the Club of Rome*, D. Gabor, U. Colombo, A. King, R. Galli, Pergamon Press, Oxford, etc. 1978, pp. 2-4.

[2] *Ibid.*, p. 213.

[3] *Ibid.*, p. 226.

but where are the mechanisms and institutions to make such a policy possible? More specifically, the same Science Ministers pointed out the need for research on the process of government itself."[1]

The propositions put forward by that meeting are closely connected with the main conclusion drawn by the authors of the Fourth Report, which they formulate in their preface: "The study has demonstrated the need for changes in institutional policies if research and development are to be effectively cultivated and applied."[2]

Such, in brief, is the main content of four reports to the Club of Rome. There is no doubt that these reports have done a great service, by formulating the meaningful problems in the destiny of mankind, describing the difficulties and contradictions of the existing situation, showing the dangers threatening mankind if the present situation continues with the present trends in its development, and drawing attention to the need for global social and political changes.

Some well established research groups have criticised these reports. The above-mentioned *A Critique of the Limits to Growth* contained a sharp criticism of the approach and conception in the First Report. The Massachusetts Institute of Technology models, the authors say, do not accord with the actual world: "Malthus in, Malthus out".[3] The distinctive feature of the MIT effort is a combination of the economics with modern environmentalist trends. Accordingly, they focus on three of the essential differences between their views and those of MIT:

1. They put much greater emphasis on the political and social limits to growth than on the purely physical limits.
2. They believe that the MIT group underestimated the possibilities of continuous technical progress.
3. There is much stronger evidence of serious maldistribution of the large resources which are now devoted to R&D.

The critics of the First Report disagree on the relative cost of minerals and diminishing returns from their use.

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[1] *Ibid.*, p. 217.
[2] *Ibid.*, p. XIV.
[3] *Thinking About the Future. A Critique of the Limits to Growth.* Ed. for the Science Policy Research Unit of Sussex University by H.S.D. Cole, Christopher Freeman, Marie Jahoda, K.L.R. Pavitt, Chatto & Windus for Sussex University Press, 1973, p. 8.

"Neither of these assumptions is historically valid. The relative cost of minerals has remained roughly constant, and has not increased over the past 80 years as a consequence of diminishing returns. And new economically exploitable reserves are being discovered all the time.

"There is little reason to think that this historical trend is bound to change in future... and there appear to be no physical limits likely in future to slow down productivity increases and innovations in the industries producing capital goods for mining, exploration, and processing".[1]

Any physical limits to agricultural production disappear beyond the time horizon of the model. The main problems of nutrition in developing countries, the Sussex researchers say, consist rather in political than in physical limits. A combination of technical progress and rational use of world resources in the production of food could push back these physical limits well beyond the time horizon of the MIT model.

Objecting to the idea expressed by Meadows et al. that society will not have enough resources to develop the sphere of the services, the critics are quite right in saying that knowledge and skills in the sphere of production and the dissemination of knowledge and the sphere of the services are the main dynamic factor, so that capital proper merely embodies the resources of society for a time.

As for the socialist countries, they believe that the sphere of the production of services and the dissemination of knowledge and spiritual values promotes the growth of society's spiritual potential, i.e., the perfection of man, who is the subject of the progress of science, technology and production.

The "Limits to Growth" conception is also being contested by a group of analysts headed by Herman Kahn of the Hudson Institute. In their work, which is entitled *The Next 200 Years*, they present a scenario for the development of the world in the light of a "cautious optimism". They write: "Given slow but steady technological and economic progress and an ultimate world population below 30 billion, it should be feasible to attain economic living standards markedly better than current ones."[2]

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[1] *Ibid.*, p. 41.

[2] Hermann Kahn, William Brown and Leon Martel, *The Next 200 Years. A Scenario for America and the World*, *Associated Business Programmes*, London, 1977, p. 12.

But the standpoint of the "cautious optimist" implies the preservation of the order which exists in the capitalist countries. "Both the gaps and improving technology will tend to accelerate development in poor countries. Attempts to force a rapid equalisation of income [meaning efforts to change the social system—*S.H.*] would guarantee only failure and tragic consequences."[2]

The fourth standpoint—that of the enthusiast of scientific, technical and economic progress—is even more optimistic. "New and improving technologies (agronomy, electronics, genetics, power generation and distribution, information processing, etc.) aided by fortuitous discoveries (e.g., ocean nodules) further man's potential for solving current perceived problems and for creating an affluent and exciting world. Man is now entering the most creative and expansive period of his history. These trends will soon allow mankind to become the 'master' of the solar system."[2] As a result, the authors believe that "plausible and realistic scenarios can be written consonant with a view that sees the world"[3] in the light of "cautious optimism" and supplemented with enthusiasm for scientific, technical and economic progress. There are now requirements and potentialities for further growth. True to their social stance, the authors add that "...because America and the rest of the nations of the developed world *do* use resources so intensely, there will be stimulation, not depression, for the economies of the less-developed countries."[4]

Both optimistic standpoints—that of the "cautious optimist" and of the "enthusiast of scientific, technical and economic progress"—are informed by the urge to preserve the capitalist system. The authors say: "All countries can be expected to become wealthy within the next 200 years. Any lesser scenario would be unreasonable or simply an expression of some exceedingly bad luck or bad management. The gap is a false issue possibly conjured up by neurotic guilt."[5]

Meanwhile, in the United States national income per head in 1976 came to $ 4,345, in Latin American countries

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[1] *Ibid.*, p. 14.
[2] *Ibid.*
[3] *Ibid.*
[4] *Ibid.* p. 14.
[5] *Ibid.*

from $ 120 to $ 465, in African and Middle East countries from $ 46 to $ 350 and in South-East Asian countries from $ 56 to $135. That same year, US corporations had before-tax profits totalling over $ 120 billion (with after-tax profits of $ 73 billion), while the country had nearly 8 million unemployed; from 1971 to 1977, strikes in the country accounted for 250 million man-days. In the richest capitalist country, millions of men and women live below the official poverty line, on the one hand, while some are ranked as millionaires and billionaires, on the other. That is what the authors of *The Next 200 Years* call a false issue possibly conjured up by neurotic guilt. That is what 15 years ago, Professor Galbraith called private affluence in the midst of public squalor.

The Sussex University group suggested that the authors of *Limits to Growth* took their particular stand because of the "intellectual mood of our era.... This disillusion with the healing properties of capitalism has combined with a generalised and widespread feeling of despair at the apparent breakdown of certain societal values."[1]

The real difficulties and alarming trends brought out by the MIT Report do not at all require a halt to progress but are altogether incompatible with the preservation of the capitalist order. Kahn, who seeks to combine the perpetuation of capitalism with scientific and technical progress, displays an optimism that diverts from the real ways of human progress.

The mature socialist society, which has been built in the USSR, is not separated by a wall from the rest of the world, for all the people on the globe have a common biosphere and largely common ecological problems. The demographic and economic trends in the developed capitalist countries and the young states exert some influence on the economy of the socialist countries. There is no doubt that the solution of all the global problems of the modern world depends above all on the preservation of peace throughout the world. The Soviet Union, being well aware of this, has been doing its utmost for the wellbeing of our world, in a tireless struggle to make the detente irreversible, and to assert peace and peaceful coexistence. There are many obstacles in the way created by the leading capitalist

[1] *Thinking About the Future*, p. 203.

countries, but the Soviet Union's economic, scientific, technical and structural policy is an optimistic one.

All the statistical data show that the highest points of the "population explosion" have been passed. Analysis shows that economic growth, helping to prolong the human life-span, simultaneously slows down the natural increase in the population. The Hudson Institute has estimated that the switch from high to relatively low rates of population growth was effected in the following periods: by the developed countries of Western Europe and North America—150 years (1775-1925), the Soviet Union—40 years (1910-1950), and Japan—only 25 years (1935-1960). Since 1950, population growth rates have been declining throughout the world, and the trend has continued. The following data illustrate this process in the developed countries.

Natural Increase per 1,000 Persons

	1950	1965	1970	1975	1977
USSR	17.0	11.1	9.2	8.8	8.5
USA	13.9	10.0	8.9	5.8	5.8
FRG	6.0	6.7	1.3	—2.4	—2.1
France	7.9	6.6	6.1	4.8	3.1
Great Britain	4.5	6.8	4.5	1.4	—2.1
Italy	9.8	9.2	7.1	6.2	4.3
Japan	17.3	11.5	12.0	12.1	10.0

We find that there is an already absolute reduction in the population in the FRG and Great Britain, while the increase in France, Italy and the United States ranges from 4.3 to 5.8 per 1,000.

In the 1960s, birth rates dropped in 15 developing countries. These facts give no ground for predicting a population disaster, as Meadows and her colleagues do. Marie Jahoda of Sussex University is quite right when she says: "Man's fate is shaped not only by what happens to him but also by what he does, and he acts not just when faced with catastrophe but daily and continuously.... If the Malthusian formula is applied to Britain, for instance, the country

should now have well over 400 million inhabitants."[1] In 1976, the United Kingdom had a population of 56 million.

As for the natural resources crisis, the MIT group, as its critics rightly say, has highly underestimated the potentialities of the STR.

Energy problems are being tackled on a multilateral basis. First of all, there are great deposits of the traditional fossil fuels (oil, gas, coal, shale and tarry sands). According to Kahn and his colleagues, the world's proven deposits of traditional fuels will last mankind for 102 years, and potential fuel resources, for 500 years. In addition, among its assets mankind also has uranium and fast-neutron reactors, and the prospect of using thermonuclear energy, which has virtually unlimited capabilities. The need to avoid the danger of "thermal pollution" of the atmosphere in consequence of the extensive production of "man-made" energy with the use of mineral fuels and atomic energy, will stimulate progress in the use of solar energy, a point made above. If the fairly complicated technological problems are solved, the Hudson Institute expects that with an efficiency of 10 per cent, the use of only one per cent of the Earth's surface could meet the world's energy requirements of the year 2000.

The second important line in tackling energy problem is connected with progress in techniques and a reduction in its energy-intensiveness, and also with the progress of technology and an increase, on that basis, of the efficiency of power installations. Low-energy technology is a key problem of scientific and technical progress. One of the most important tasks facing mankind is to reduce the energy-intensiveness of social production.

The underestimation of the potentialities of the STR by the authors of the First Report is most evident on the question of production materials. One of the key features of the current STR is precisely the fact that the revolution in technology has gone hand in hand with a real revolution in the production of materials. The development and mass use of man-made (synthetic) materials with pre-set properties has virtually just begun and is gathering speed and momentum. The potentialities of organic polymers have not yet been worked out, but their development is being

[1] *Thinking About the Future*, p. 211.

followed by that of inorganic polymers, notably, those based on silicon, a raw material whose deposits are virtually unlimited.

The present state of the production of foodstuffs and the perceived prospects in this sphere do not give ground for the catastrophic prospects suggested by the authors of *Limits to Growth*.

First of all, the potentialities of the traditional foodstuffs produced by traditional methods are far from exhausted. Crop yields of cereals and legumes grew from 1.19 to 1.84 tons per hectare in the socialist countries from 1960 to 1977, and from 1.4 to 1.83 in the rest of the world. In a number of countries, however, the rise in the crop yield was much more pronounced: in the USSR, from 1.09 to 1.5; in Hungary, from 1.96 to 4.04; in France, the FRG and Great Britain it was from 4.0 to 4.5 in 1977. There was also a marked increase in the crop yields in the developing countries: in India, from 0.85 to 1.14; and in Argentina, from 1.26 to 2.09.[1] Two kinds of factors will have an influence on the further growth of crop yields: improvement of the soil through fertilizers and irrigation, and the use of genetics and selection in developing high-yield varieties (HYV) of plants. Kahn and his group suggest the following potentialities in this sphere[2]:

Factors raising yields	Crop-yield coefficients	
	Conservative	Optimistic
Improved use of fertilizers	1.5-fold	2.0-fold
Irrigation	1.5-fold	2.0-fold
HYVs	2.0-fold	2.5-fold
Other inputs	1.2-fold	1.4-fold

A large reserve for increasing crop yields (conservative—1.5, and optimistic—2.0) is the possibility of accelerating the rotation of crops. In addition, it is possible to increase the area under crop (conservative—2.5, optimistic—4).

[1] *Narodnoye Khozyaistvo SSSR v 1977*, FAO figures for the rest of the world.

[2] Herman Kahn et al., *The Next 200 Years*, p. 125.

Food output can be tangibly increased by means of new plant-growing methods like hydroponics, and the nutrient-film method, its simplified version. Finally, over the long term, one should also take into account the potentialities of chemically producing the so-called uni-cellular protein and other types of man-made and synthetic foods. Altogether, the potentialities for boosting crop output come to a total of between a factor of 20 and 110.

The achievements of scientific and technical progress can also be used in livestock breeding. Genetics and selection can be used to develop highly productive specialised breeds of cattle and to advance the production of feed through a combination of cropping produce, mixed-feeds and products of the microbiological industry, the basis for a large growth of stockbreeding output.

An ecological policy that is balanced and conducted on the state and international level is certainly capable of averting ecological crises and of allowing economic growth with ecological harmony.

In its five-year and long-term plans, the Soviet Union has not set itself any "limits to growth". The Soviet economy is not threatened with population, energy, ecological or economic crises. The Soviet people look to stable rates of economic growth, a balanced build-up of the material and technical basis of communism, and utmost consolidation of society's economic, production and spiritual potential.

The scale of priorities for the foreseeable future will rank high, alongside the further development of material production, accelerated development of the material and technical basis for the sphere of the services, and the sphere of the production and dissemination of knowledge and spiritual values. The growth and consolidation of the spiritual potential is a key factor of dynamic development and sound economics.

At the same time, economic growth and realisation of scientific and technical achievements also confront the Soviet Union and other socialist countries with a number of major tasks in the ecology, which were described in Paragraph 6 of Chapter Four. However, the socialist society does not seek any panacea from local or global catastrophes, but the elaboration of a *strategy for solving* the problems of state economic, scientific, technical and structural policy in the individual socialist countries and within the socialist

system as a whole, and also problems in world development to the extent to which the socialist community countries can exert an influence on it.

That is the attitude taken by the socialist society in meeting and actively shaping the "morrow" of the STR.

Its contours appear to have two main lines: an abundance of "pure" energy obtained through thermonuclear synthesis, and the extensive use of the advances of the whole biological-science complex in the natural sciences, in technology and production.

Our view of the abundance of energy, which the whole of mankind wants, is based on the criteria of the energy-intensiveness of social production and the trends in its changes, and in the light of the logic of development of the power engineering itself and the related natural sciences. Considering this abundance in terms of the future of the STR, we arrive at the conclusion that it can be effected on a "pure" basis (i.e., without radio-active waste or the contamination of the environment) through the use of thermonuclear energy not earlier than the end of the 20th century or the beginning of the 21st century.

The new trends in scientific and technical progress advancing parallel and catching up with each other could produce some highly positive effects. There is the "biology" echelon, which in the future could initiate the development of fundamentally new technology that will upset our received notions of the nature and energy-intensiveness of material production.

A close look at the technological basis and methods of the technical projects now being put through to realise most of the STR achievements shows that these are essentially traditional.

As in the elementary steam engine, power, including atomic power, is still obtained through the conversion of high-temperature heat into mechanical energy, and the latter into electric power. Motive power is obtained on the same principle. Chemical processes, including organic synthesis, are based on high temperatures, pressures and speeds. In manufacturing, even where automated equipment is used, mechanical cutting or mechanical pressure still prevail.

This view on the achievements and potentialities of the STR does not in any sense minimise their great importance, but is based on the real fact that in the surrounding world,

all over the globe, we find "living engineering systems" which exist and are multiplied, whose techniques of generating and transmitting energy, transforming and obtaining substances, and automated processes of control are remarkably purposeful and reliable, while being economical to a totally inconceivable extent when compared with the most progressive of all the existing types of machinery.

This has been well described by I. B. Litinetsky, who says: "It is assumed that the Earth has been in existence for nearly 5 billion years, and that life originated in the most primitive form 1.5-2 billion years ago. In the process of the subsequent ruthless natural selection over millions of years the strongest animals and plants survived, for they were best adapted to definite natural conditions, made fewer mistakes, and acted more rationally. As a result of this protracted evolution, Nature has created on the Earth a vast treasure-house with an immense number of amazing specimens of living engineering systems."[1]

At the present stage, although science is beginning to study the production systems "engineered" by Nature, the great designer, there is still a long way to go before the substance and secrets of these processes are established. The muscle, a high-polymer motor, has a relative efficiency that is unparalleled anywhere in engineering and is amazingly economical.[2]

The generation and conservation of biochemical-reaction energy and subsequent transmission of excess energy for its use in other reactions in living organisms is exceptionally efficient.

Academician Semyonov had this to say about the chemistry in "living machines": "In plants, and especially in animals, complex syntheses run in the course of a minute, but in the laboratories they frequently take months of work.

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[1] I. B. Litinetsky, *Talks on Bionics*, Moscow, Nauka Publishers, 1968, p. 7 (in Russian).

[2] Academician Semyonov writes: "The relative efficiency of the conversion of chemical energy directly into muscular work comes to 70 per cent, which is nearly 50 per cent more than the relative efficiency of the best electric-power plants. That is not surprising, because the energetics of the organism is quite different from that of industry and makes it possible, in principle, to convert energy with an efficiency of 100 per cent. An amazing example of this is the conversion of chemical energy into light energy by fire-flies" (see "About the Energetics of the Future", *Nauka i zhizn*, No. 10, 1972).

"Once again we stand on the threshold of a revolution in chemistry, this time induced by biology. While our chemical industry makes use of high temperatures and pressures, the organism is capable of producing the same reactions under normal temperatures and pressures.

"The cell is a mini chemical power-plant with special shops: battery charging, distribution of substance by zone, the transport of amino acids, the assembly of proteins. This assembly is controlled by a special 'controlling machine'. The parts are prepared and the protein molecules assembled with greater precision than the assembly aircraft parts. Nature has made this plant with a perfection for which we at our plants are only striving."[1]

The organisational and structural level of living systems, their systems of ties and automatic regulation of molecules bear no comparison with the most modern and advanced technical systems.

The self-regulation of cellular processes is so reliable, flexible and adaptable that it surpasses anything achieved in engineering. In cells there is a continuous self-adjustment to a new and optimal regime of operation (in the light of the changing environment).

Finally, the crowning achievement of all living systems, which still lies beyond man's reach, is the perfect "cybernetic mechanism", *the human brain and nervous system*, which fulfil in the most perfect way the functions of collecting, processing and retrieval of information.

> There are various estimates of the volume of the human memory, but they all agree that it is measured in billions of units of information—from 10^{10} to 10^{15} and over. Let us bear in mind that the memory of modern computers is capable of storing from 10^6 to 10^7 bytes with a relatively large size of the machine itself.
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> In addition, the human memory has virtually unlimited reserves, reserve capacities, for in no instance has the human brain been so filled up as to fail to take in additional information. By contrast, all the memory of a computer can, of course, be filled up.

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[1] "About the Energetics of the Future", *Nauka i zhizn*, No. 11, 1972, pp. 27-28.

The brain is capable of using its information with an ease and flexibility that are inconceivable in the most perfect engineering devices for the time being, and is capable of thinking by association, or of producing conjectures, hypotheses and brilliant insights.

Closely connected with the functioning of the brain is the nervous system and its living elements: nerve cells and neurons.

In the nervous system of humans and also of tens of millions of living organisms, we have unprecedentedly reliable, small and economical devices, which are self-instructing, adaptive, self-regulating and self-organising, and which store, process and transmit vast volumes of information. The latest computers are only a pale analogue of these devices. The system of neuron is quite evidently the prototype of automated electronic systems.

Those are some of the most general aspects of the energetics, motive, chemical, automatic and cogitative potentialities of "living machines". There is no need to detail the practical importance for material production of the principles on which "living machines" operate.

The "locators" which many living beings have are highly perfect and economical. The bat's locator is a hundred times more sensitive and stable than the most perfect modern radars. Considering the relative size of the locators and of their objectives, one will find that the bat's locator is several million times more effective than the radar of a plane per unit of capacity, and almost 1,000 times more efficient per unit of weight.

Man has outstripped birds in the speed and distance of flight, but modern aircraft, including jets, have a long way to go in terms of economies. The following data show the relative efficiency of modern turbojets and birds: airliners, like the IL-62 and the TU-154, which are up to the highest world standards, have a weight of about 14 kilogrammes per engine h.p. For the eagle, the figure is 70 kilogrammes, and for the stork, 135 kilogrammes, which means that it is ten times more economical than the turbojet giants.

Academician A. I. Berg says that bionics, a young but highly promising field of science, has the task of making an in-depth study of the functions, specific features and phenomena of living nature in order to apply this knowledge in the technical world.

Technical developments based on living-nature phenomena have already been effected in science and practice.

Consider the calamities inflicted by atmospheric and other natural cataclysms, like droughts and floods, storms and hurricanes, earthquakes and volcanic eruptions. Everyone knows that despite the large-scale and very costly activity of the weather bureaus, their forecasts frequently turn out to be erroneous. Meanwhile, numerous living systems—animals, birds, fish, insects and plants—have absolutely infallible means of anticipating these natural phenomena.

Researchers at the Biophysics Department of the Moscow University have created an electronic device based on the same principle on which the jelly-fish forecasts the arrival of storms (infra-ear). Their tests showed that its mechanism is capable of forecasting a storm and its strength some 15 hours in advance.

The efficiency of the dolphin's hydro-dynamic secret will be seen from the fact that in order to attain a speed of 30 knots (56 km per hour), a speed at which schools of dolphins frequently travel, their muscles, according to various scientific calculations, have to be roughly 7-10 times more powerful than they are in fact. Studies have shown that the secret lies in the structure and properties of the dolphin's skin, i.e., in the "coating" of this living "ship". Experiments and tests have shown that it is possible to reduce water resistance by 40-60 per cent.

Making use of these "secrets" for coating the inner surfaces of tubes (an imitation of the dolphin's skin consisting of a polyester-based urethane resin) made it possible to reduce pressure losses in the piping of liquids by 35 per cent.

But one must also bear in mind that scientific cognition now sheds light only on some individual components of all these systems, and that it is still very far from having a full understanding of the mechanism of the ties which

transform these components into coherent and functioning systems. That is why Academician Engelgardt attaches so much importance to the problems of "integratism".

The full discovery of the chemical and physical principles and—perhaps most importantly—of the organisational and structural devices and functioning of "living machines", and then the mastery (if that is at all possible) of the methods of reproduction of all the systems in their unique complexity, efficiency and simplicity would amount to a hitherto inconceivable and most rational change in the fundamental principles of material production and its transition to a totally new and higher stage of development.

The advances in the biological sciences and bionics open up possibilities for technical solutions which for the time being will not be found either in engineering or in "living systems". The use of the bio-currents of the brain and the bio-electrical method open up the prospect of direct transmission of command signals from man to technical systems, i.e., directly from the central nervous system to the control organs of machines.

Analysing the prospects opened up by Soviet research into bio-electrical control, Norbert Wiener, the founder of cybernetics, wrote in his book *God and Golem* about the possibility of finding a totally new and direct contact between man and machine and the development of systems in which unprecedented mechanical structures will obey orders from the brain as do the muscles of the living hand.

Back in 1959, Academician Blagonravov declared: "The idea is to create a robot that will respond to your thinking. That is not mysticism, that is not fantasy!"

Thus, alongside an abundance of pure energy, we divine the possibility of fundamental changes in the principles of technology and the whole of material production, a prospect that is not in science fiction but one that is being studied by thousands of scientists.

The application to material production of the technical principles being discovered by the biological sciences in the organic world and the gradual shaping of a stage (or stages) in the development of large-scale machine production at which these principles will be increasingly prominent is a reality although remote.

Up to now, we have been considering the "morrow" of the STR connected with the use in technology and social pro-

duction of the amazing "technical achievements" of living beings.

All of these tremendous and unprecedented potentialities characterise one aspect. The second, equally important and, in terms of its potential consequences for mankind, perhaps the more important aspect is the possible effect of the revolution in biology on living beings, especially on man himself.

In much the same way as the current STR has spawned a whole complex of macro-ecological problems, which now and again have a tremendous influence on the global destinies of mankind and the planet Earth as a whole, so the biological revolution, which is now in the offing, is fraught with equally global macro- and micro-ecological problems.

There is no doubt that the tremendous advances in biology and genetics, backed up by achievements in biophysics and biochemistry, and also in molecular biology, together with the medical sciences and pharmaceutical chemistry will bring even more successes in the selection of highly productive animals and plants, in the elimination of congenital defects in human beings, in the curing of disease, in prolonging the life-span and the period of man's full-value working capacity. At the same time the foreseeable prospects and potentialities of biology give ground to consider other aspects of its impact on the future of mankind.

It is clear that the socio-economic consequences of the STR are largely determined by the social system, by the prevailing relations of production. Imperialism has converted the latest advances in physics into the tragedy of Hiroshima and Nagasaki. The advances in organic chemistry took the form of the thousands of tons of napalm dropped on Vietnam, Laos and Kampuchea. The advances in chemistry and biology were used to wipe out vegetation on tens of thousands of hectares in Vietnam. Advances in biology are being used at Fort Detrick, USA, to develop biological weapons. Nerve, tear and other gases demonstrate the use of advances in the biological sciences in suppressing strikes and demonstrations in the imperialist countries. Electronics was extensively and comprehensively used for the monstrous carpet-bombing of Vietnam.

That is why the leading biologists of the developed capitalist countries view with great alarm the possible consequences of the biological revolution. Professor Salvador

Edward Luria has declared that he is seized with a sense of boundless fear when he thinks of what could happen if the discoveries in genetics were wrongfully applied.

Let us try to imagine in more concrete terms the potentialities of the revolution in biology in terms of its impact on living beings. In this context, a comparison of scientific prognostications and assessments connected with the progress of the biological revolution as expressed by Soviet scientists and scientists in the major capitalist countries is highly indicative.

In Chapter Three, I described the mechanism of the regulation and self-regulation of the life activity and functioning of living beings. What will it mean for man and society to learn to control and regulate these processes?

Academician A. Dubinin, writing in *Pravda*, says: "Solution of the problem of directed mutations is the cherished goal of genetics. Thus, the ideal, the dream of those who work in agriculture is a high-yield strain of wheat producing 100 centners of grain per hectare, non-lodging, resistant to disease, cold and hot dry winds, containing much high-quality protein and having a number of other characteristics.... Every characteristic of the organism is determined by genes. If we could purposefully change them, it would not be difficult to 'make up' a combination that would give us the desired variety of wheat. And not only of wheat. All the other problems in the selection of plants, animals and micro-organisms would be solved." He goes on to consider the artificial synthesis of genes and of separating isolated "live" genes from the cell, and adds that "the practical perspectives of this would be truly fabulous. It would be possible, for instance, to cure those suffering from birth defects by withdrawing the corresponding gene from the cell and substituting a healthy one for it. The same procedure of substituting the necessary gene for an undesirable one could transform the selection of animals and plants."

The well-known US biologist James Danielli says that genetic engineering opens up fresh prospects for transplanting into vegetable cells genes capable of substantially increasing the content of protein rich in amino acids, which are the most important for man. This, for its part, would help to reduce the consumption of proteins of animal origin: meat, milk, butter, etc.

Scientists are already faced with the practical problem of developing "superplants" that would combine properties like resistance to drought and disease, which barley has; the root system of leguminous plants which is capable of self-fertilisation in symbiosis with nitrogen-fixing bacteria; and the high yields and nutrient properties of wheat.

A key sphere for the application of genetic engineering could be the development of more productive cultures of nitrogen-fixing bacteria and algae, and the transfer of a set of bacterial genes responsible for the fixation of nitrogen into the genome of agricultural crops.

In order to feed the world's population on the products of the "green revolution" by the year 2000, upwards of $ 100 billion would have to be invested in factories making nitrogen fertilisers. Compare this with the estimated $ 100 million needed to develop suitable genetic engineering techniques for plants, and the choice looks simple, says Danielli.[1]

As for birth defects, US medical statistician, Gabriel Stickle[2], has estimated the number of future life years lost (1967 figures) — 36 million, i.e., 2.25 times more than the years lost due to heart disease, cancer and stroke taken together. According to the National Institute of General Medical Sciences in the United States, 15 million people in the country have congenital diseases affecting their daily life. Genetic factors are behind something like 40 per cent of all the cases of child mortality. In the United States, 25 per cent of the hospital beds are occupied by people suffering from various genetic diseases.

There is every reason to hope that in the foreseeable future advances in molecular biology and allied sciences will help to discover the mechanism of immune response and make it possible to control it. This has a close bearing on the solution of problems in overcoming incompatibility in organ and tissue transplants. This, for its part, would give the green light to the transplantation of organs and restorative surgery in every part of the human organism. That would be a great stride forward in the preservation and prolongation of human life.

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[1] See *New Scientist*, No. 64, 1974, p. 166.

[2] *Prospects for Designed Genetic Changes*, No. 4, Bethesda, Maryland, 1971, p. 24.

Advances in the biological and allied sciences, together with the successful development of the corresponding devices and techniques will create in the foreseeable future a very real possibility for active and purposeful influence on human heredity and the combating of some hereditary diseases.

At the end of 1974, Academician V. Timakov said: "The discovery of the genetic role of nucleic acids, the cracking of the heredity code and the clarification of the complex structure of genes warrant the assumption that this means not only cognition of the in-depth processes of life, but also the creation of conditions for influencing them, for directing the life activity of the organism and correcting the 'mistakes' which Nature now and again makes and which are the cause of disease."

Concerning the elimination of harmful manifestations of the incorrect functioning of the organism, Academician V. Timakov writes: "Prospects are now being opened up for eliminating the prime cause of these through the introduction into the organism of genetic material to correct or substitute for the defective genes. This new and important line in science has been called 'genetic engineering'."[1]

"In the most recent period," says Academician Engelgardt, "a new and promising branch of molecular biology has emerged: genetic engineering. It has shown the possibility of operating with genes as a real, one could say, tangible physical substance."

Connected with the use of genetic engineering is the discovery of a new enzyme with unusual potentialities, which has been designated as "reverse transcriptase", or "revertase" as Soviet biologists call it. Academician Engelgardt says that the discovery of this enzyme is ranked among the major discoveries in molecular biology in the recent period. It has become one of the chief instruments of gene engineering. Its potentialities will be seen from the remarkable discovery by the Indian scientist G. Khoraa, working in the United States, who a few years ago effected the complete chemical synthesis of a section of double-stranded DNA, i.e., produced an artificial gene. Still, this brilliant result called for intense efforts by dozens of scientists over a period

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[1] *Pravda*, November 17, 1974.

of five years and at the cost of several million dollars. In this connection, it is of note that Moscow scientist L. Kiselyov had synthesised the gene of a component of haemoglobin, which is roughly four times larger than the nucleic acid gene synthesised by G. Khoraa. Thanks to the use of revertase, this synthesis was performed in a small laboratory by the efforts of two or three researchers over a few weeks within a modest laboratory budget.

Although genetic engineering is now in the initial stage, it has very extensive potentialities and sphere of application.

This includes the synthesis of genetic material so as to implant the gene obtained, say, into the heredity complex of the micro-organism being restructured. It also includes the use of bacteria and viruses as peculiar biological "breeder", for under definite conditions the genetic complexes implanted into them tend to replicate a thousand-fold in a very short time. One could expect that subsequently drops produced by bacteria or virus could be used for research or the production of enzymes, hormones or vitamins on a commercial basis: these systems separated from living cells and invisible to the naked eye are unusually productive. Genetic engineering opens up the tantalising prospect of borrowing the genetic complex from nitrogen-fixing bacteria to assimilate nitrogen from the atmosphere and transplant it into the genome of wheat so as to enable wheat itself to synthesise the nitrogen fertilizer it needs. Such an operation could save huge sums of money and markedly lighten the load on the chemical industry. Experiments are now already under way in structuring plants capable of "fertilizing" themselves.

The technological use of genetic engineering is highly promising, and it can make a big contribution to the development of new biological techniques, which, according to the Soviet scientists, will be extensively used over the long term. Noiseless, waste-free and pure production lines, with wholly man-made systems and systems combining living elements with man-made elements modelled on natural elements, will replace many of the existing enterprises which are extremely inefficient in the use of raw materials, require much energy, and have a negative effect on the environment.

Genetic engineering opens up even more unusual and attractive prospects. It will help to correct the "mistakes

of Nature", to correct the defective transcripts in the heredity of individuals and to breed animals or vegetable organisms with pre-set and even perhaps with altogether unusual properties, to control the growth and development of organisms, and one day to discover the secret of the origin of life on our planet.

Progress in the biological sciences carries mankind close to the fundamental question relating to the theory of cognition, to the problem of the substance of life. It was stated, that at every level of biological organisation, from the lowest (virus) to the highest (human organism), no simple boundary line can be drawn between the organic and the inorganic. There is only a scale of gradations imperceptibly approaching some limit.

Scientists have already produced some protein molecules (see Chapter Three). These and many other facts enabled Engelgardt back in 1969 to answer this question: is the "synthesis of life" conceivable?

He said that, without letting ourselves be carried away with over-hasty declarations and an unhealthy element of eye-opener, one could still safely express the confidence in attaining the goal which but recently appeared to be unattainable: the artificial creation of the simplest forms of organic matter.

In his opinion, we now face a paradox.... It is that we have, perhaps, obtained in experiments something organic, without quite knowing what life is after all. We should not in any way be discouraged by this paradox. There is no doubt that this is precisely the way, apparently upsetting the sequence of logical stages, that the crucial step will also be taken in the advance to the ultimate goal, the cognition of the substance of life.

In striking contrast to these views of Soviet scientists are the statements on the same problem by scientists and analysts in the developed capitalist countries.

A recent book published in Britain by Gordon Taylor, *The Biological Time-Bomb*, describes the extreme situations possible to emerge in this area, in the conditions of present-day capitalist society.

In his Chapter One, the author says: "We can now create ... substances which never previously existed in nature... We shall even be able to create forms of life which never existed before. To some the prospect may seem terrifying,

but as in all such advances, the new knowledge can be used for good or ill. The first consequences will certainly be a great extension of responsibilities. ...a task which many people find burdensome."[1]

What would a revolution in biology signify for mankind, considering that its great discoveries could be used by the imperialist forces against the interests of man and society as a whole? Taylor says that biological war could be carried on for decades without the enemy even being aware of it, by infecting the enemy with flu viruses or enfeebling heredity. "And who knows whether this is just a speculation? Perhaps there are nations consciously waging this kind of warfare now. ...There could be actual gene warfare, with viruses used to carry new genetic material to cells and tamper with the genes of another nation without their ever realising the fact. History would simply record, as it has so often done in the past, that such and such a nation rose to power while certain other countries entered a decline."[2]

Taylor goes on to interpret the biological revolution in the spirit which is characteristic of many scientists and analysts in developed capitalist countries when they consider the prospects of human-organ transplants. He asserts that the development of biomedicine is bound to widen the gap between rich and poor countries, and that tremendously complicated problems will arise in the developed countries themselves. "One of the more serious of these, I suspect, may be the creation of élite groups, or haves and have-nots: privilege is always unpopular, but takes on peculiar importance when applied to life-prolongation or raising of intelligence."[3] Let us add that these apprehensions are well grounded when it comes to the capitalist society with its inherent class antagonisms.

But one has to consider these apprehensions which spring from inadequate capabilities in anticipating all the possible consequences of influencing living systems. If a particular hereditary modification proves a mistake, it may take generations to ascertain the fact and several generations more to undo or correct it. Taylor gives a hypothetically

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[1] Gordon Rattray Taylor, *The Biological Time-Bomb*, Thames and Hudson, London, 1968, p. 16.

[2] *Ibid.*, p. 184.

[3] *Ibid.*, p. 215.

extreme picture: "The practice of culturing viruses and looking for new mutants creates a risk that a dangerous new mutant might escape and set off an epidemic, against which the population of the world would be helpless, since the natural defence systems would be unable to cope with it."[1]

All of this is naturally of concern to scientists who are aware of their responsibility for the future of mankind. Specialists draw attention to the fact that very simple techniques for manipulating DNA fragments have already been developed and could be used by many researchers who may not have enough knowledge or experience to anticipate the potential dangers of some genetic experiments. Of course, one must also reckon with the fact that the injection of foreign genetic material into a patient could affect not only the target cells, but also the sex cells. Until the effects of this on the patient's offspring are ascertained, there will be—theoretically, at any rate—the danger of individuals appearing with new hereditary anomalies.

Nevertheless, the correction of genetic defects on the level of sex cells is one of the most important and highly promising trends of science, technology and practice.

In the United States, the National Academy of Sciences has set up a Committee on Recombinant DNA Molecules which, considering that by early 1974 relatively simple methods for combining DNA with the DNA of bacteria had been sufficiently worked out, issued a statement warning scientists in this field against the creation of "dangerous molecules".[2]

Many scientists in the West, who realise the prospects and potentialities of the STR, agree that they do not accord with social conditions and the social conceptions of present-day capitalism. This idea was expressed by the well-known US scientist John McHale in a book entitled *The Future of the Future*, in which he says: "While science and technology must be allocated a prime role in the changing of past and present, the more crucial aspects of the future are now more clearly nontechnological, in the traditional sense. The 'hardware' to solve many of our physical problems is available for use. The 'software', or social thinking, through

[1] *Ibid.*, p. 223.

[2] See *Nature*, 250, 1974, p. 175; *Science*, 185, 1974, p. 303; Proc. Nat. Acad. Sc., USA, 71, 1974, p. 2593.

which we may apply our developed capacities in humanly desirable terms, is less than adequate.

"The models of human society, of our institutions, and of our social capabilities and relatedness, with which we still operate, restrict much of our future thinking within obsolete historical conditions...

"The constraining myths that bind us to obsolete forms, old fears, and insecurities may be our most dangerous deterrents. Our traditional attitudes and ideologies are inadequate guides to the future, serving mainly to perpetuate old inequities and insecurities."[1]

The socialist, and even to a greater extent the communist, society will alone ensure the full realisation of the achievements of the biological and biogenetic revolution, because it alone is capable of taking decisions in which the interests of society and those of all its individual members are harmonised instead of being at odds with each other.

That is why there is such a difference in the very tone in which the problems of the biogenetic revolution are set forth by Soviet scientists, on the one hand, and by bourgeois scientists, on the other. The Soviet people look with optimism to this revolution, as they do to the current scientific and technical revolution, to the prospects and potentialities for perfecting man, prolonging his life and increasing his creative potentialities and joys in life.

But it would be wrong to assume that the decisions the communist society will have to take over these problems will be the easy ones. There arise such major economic problems as the need to set up a great network of enterprises and establishments to provide biogenetic services and enterprises in related industries, the problem of providing for a much larger percentage of elderly persons than there are today without reducing the pace of the expanded economic reproduction, and the problems connected with determining the strategy of biogenetic research and development, selection of the optimal line of this research which is ideal from the point of view of the communist society, and finally, the whole complex of related moral, ethical and juridical problems. Society must be prepared for all this, because it is all connected with the morrow of the scientific and

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[1] John McHale, *The Future of the Future*, George Braziller, N. Y., 1969, p. 11.

technical revolution as it appears in the light of our present knowledge.

Taylor admits that in the capitalist world there is no agreed view on the future of the world. There is such a view in the developed socialist society. With the Marxist-Leninist theory and the more than 60 years of experience in socialist construction, our society is clearly aware of the goals it has set itself and the ideals by which it is guided in its creative effort.

In the gigantic spectrum of potentialities opened up by the STR, the collective reason of the socialist society will be able to select those that will give the greatest harmony to society as a whole and to each of its elements, including the chief and crucial element, the man of the communist formation.

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